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TIME AND MOTION STUDY
AND FORMULAS FOR WAGE INCENTIVES

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PREFACE

No diligent search in the history of the development of the industrial system is necessary to determine the one single cause which has contributed most to industrial unrest. This cause may be described briefly as the lack of an equitable and consistent method for measuring human effort and from this measure establishing a compensation which is mutually satisfactory to employer and employee. The scientific management movement covering the last two or three decades has brought forward many systems, plans, and ideas which have been of varying degrees of value to industry. Ranking with those that are recognized as being among the best of these developments is time study. Considering its economic importance in industry and its value as a means of promoting better relations between employer and employee, there has been a rather limited amount of published material on the subject. As might be expected of a comparatively new science, early development has been rapid. Some of the best-known and most widely used practices of five and ten years ago have fallen into disuse in the more progressive plants. The time-tested methods which remain, as well as the new developments that have grown out of additional experience and study, are now reflecting those qualities of maturity and permanence which promote instinctive confidence. In this book, the authors have attempted to present these time-tested principles and newer developments incorporated in a fully developed and completely described time-study and formula system.

It should be understood by the reader that the term "time-study" as used in this book carries with it the fullest interpretation. Common usage has decreed that "time-study" shall be used to identify what is in reality "time and motion study." The two are inseparable, and one is of little use without the other. There should be no confusion, however, with the methods of some modern authorities who have chosen to identify their practices by the term, "motion-study." This

term standing alone is fully as misleading as is the term "time-study" when standing alone. Motion study does not eliminate the time element any more than time-study eliminates the scientific analysis and standardization of motions. The distinction lies in the fact that motion-study, by means of motion picture cameras and comparatively elaborate and expensive methods, lays greater stress on the minute analysis of motions under more or less ideal or laboratory conditions, while time-study as advocated in this book, is designed along simpler, more practicable, and more comprehensive lines. It is a practical working system that may be applied in any industry, large or small, standard or special, with the use of simple and inexpensive apparatus, securing quick results under normal and practical operating conditions as they actually exist and with the least amount of interference with production and with the workers' mental attitudes. The authors have not attempted to elaborate on motion-study as such, partly because it cannot be separated from time study and partly because they feel that it is merely a feature of high grade analysis and standardization preparatory to the actual recording of watch readings on the time-study form.

This book is designed to fulfil a dual purpose as a textbook for technical schools and as a handbook for practical men and factory executives. While there are some points, therefore, which may not be of particular interest to the student, these same points are vitally interesting to the man who wishes actually to put in operation a working time-study system. Viewed from the standpoint of the student, Chaps. III, XVI, XXXIV, XXXV and XXXVIII may not justify intensive study. These chapters, however, are of considerable value and interest to the employer.

The book is divided into three parts. Part I takes up step by step the method of making a time study. For the sake of clearness, a large number of examples have been purposely avoided, but one that is representative and comparatively simple has been traced through each step. Attention is called particularly to the analyses and classifications of skill and effort and to the leveling method of determining standard time values. Part II is a complete exposition of the methods for constructing formulas from time-study data. Part III explains in a general way how to organize and supervise time-study,

formula, and wage-payment work in any plant. This part will be perhaps of more interest to the practical man than to the student, although it should not be neglected by the latter.

Acknowledgement is made to the Westinghouse Electric and Manufacturing Company for the cooperation which the authors have received from it. The formulas given as examples are in actual use in the East Pittsburgh, Pa., plant.

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PART I

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CHAPTER I

ECONOMIC NECESSITY FOR MEASUREMENT OF LABOR

Primitive man existed at first, independent of his neighbor, fashioning his own weapons, hunting his own food, and making his own rude clothing. As time went on, however, certain individuals became experts in making weapons, others in hunting game, and still others in making clothes. Here is recognized the beginning of the division of labor and of the various trades. One man made weapons for all his neighbors, another hunted food for the immediate community and so on, each trading the products of his labor beyond his own requirements for a portion of his neighbors' excess. This trading in commodities is known as bartering, which along with other economic factors, such as mediums of exchange and credit, is the foundation of the vast commercial activities of today.

Labor—the Commodity.—Bartering involves only the physical exchange of goods. When it became inconvenient and cumbersome actually to exchange goods for goods, mediums of exchange were developed. It then became possible to express the respective values of all commodities in commonly accepted and convenient units of measure. Beads and other such trinkets are recorded as being among the first things used in a manner similar to that in which gold and silver are used today.

Trading in commodities by means of a medium of exchange is known as buying and selling. The primitive specialist, previously referred to, who devoted his entire time to one activity, found it profitable to sell his surplus production beyond his own requirements and, with the medium of exchange thus secured, to buy other things that he needed. If he met with success, his work increased until he soon reached the limits of his

personal output. In order that his business might grow, he soon found it necessary to employ help. He then became a buyer of labor just as he already was a buyer of commodities other than those which he made. In fact, labor has frequently been classed as a commodity. Whether it is or is not strictly a commodity may be debatable, but the fact that it possesses economic value cannot be disputed.

Measurement of Labor.—Commodities or anything else of value are purchased by measure; that is, a certain quantity or number of units of a certain quality is obtained for the price paid. The units of measure vary. For instance, coal is measured by the ton or bushel, cloth by the yard, land by the acre, and brick by the thousand.

It was logical, then, that a measure should be developed for labor, and also that the units should be changed as they were found to be inadequate or unfair, just as present methods of fixing commodity values have grown from the original crude and incorrect attempts.

Slave labor was not uncommon in times past. For this, the purchaser had to pay only the market value of the slave or perhaps finance an expedition of conquest into enemy territory for the purpose of bringing back captive slaves. He then became the owner of a potential supply of labor to use as he saw fit during the lifetime of the slave. Serfs exchanged their labor for a place to live which was granted them by their feudal lords.

Under the apprenticeship system, young men, or rather their parents, contracted to sell their labor over a period of years in exchange for a working knowledge of a trade. The demand for labor increased with industrial development, and men learned to market their labor by the year, month, day, and hour. The last named is a method which is still widely employed. It is a safe estimate that there is more labor purchased today on a straight hourly basis than in any other way. This, of course includes not only productive labor, but all indirect, maintenance, and expense labor. The tendency, however, is away from this method toward fairer and more equitable plans.

Quality of Labor.—It has been said previously that commodity values are determined by quality as well as quantity or measure. Thus far, the value of labor has been discussed only from a quantitative viewpoint, the measure being on the basis of time. But it must not be overlooked that quality enters into the deter-

mination of labor values just as it does into the determination of commodity values. The statement that the hourly basis of wage payment is, in general, unfair and unsatisfactory may bring forth the argument that quality is taken into account because different classes of labor demanding different degrees of skill and experience are purchased at different hourly rates. The hourly rate of tool makers as a class, for instance, is higher than that of ordinary machinists, and the rate of cabinet makers higher than that of carpenters. This is true, but the element of quality has been only partly taken into account. Although tool makers as a class are worth more than machinists as a class, it does not necessarily follow that all tool makers or all machinists are of equal value.

Quality of labor is determined by the personal characteristics of the worker including such things as skill, effort, intelligence, experience, physical strength, endurance, and ingenuity.

Value of Labor.—Quantity alone is not an adequate measure of the value of labor. Assume that two mechanics are each given 100 small metal parts to be laid out for drilling. The two jobs are identical and both men have equally good tools and equipment with which to work. One man proceeds to lay out each individual piece by means of his scales, calipers, scribers, center punch, hammer, and other layout tools. Each piece requires approximately 3 minutes or the operator takes 300 minutes or 5 hours to complete his 100 pieces. The other man spends 1 hour in making a template to fit the work. Holes are properly located so that it is only necessary to lay the template over each piece, insert a center punch in the proper holes, tap it with a hammer, and the piece is accurately laid out. The whole operation for each piece takes only about 30 seconds, or a total of 50 minutes is needed for the entire 100 pieces. The second man thus requires only 50 minutes plus the 1 hour for making the template or less than 2 hours to do the same amount of work which the first man took 5 hours to accomplish. It is evident that the second mechanic is of considerably more value to his employer than the first simply because his labor possesses an element of greater quality. Why should an employer be obliged to pay for the additional 3 hours required by the workman who did not use his head when 2 hours is sufficient to complete the job?

On the other hand, neither can quality stand alone as a measure of the value of labor. Two men may be equally capable of turning out work of high quality, but one may produce in larger quan-

tities than the other over the same period of time, thus making himself of more value to his employer than the other.

Therefore, the judicious employer does not want to purchase merely labor, which is measured only on the basis of time as when he buys it by the hour. He wants to purchase output or useful work which, in this discussion, will be regarded as the results of labor that has been applied toward a desired accomplishment. From an economic standpoint, he is not particularly interested in the amount of labor required to produce each unit. He is more vitally interested in producing as many units as his facilities permit, assuming, of course, that the market will absorb his maximum output. It is the product itself that he sells, not the labor used in producing it. The fact that one unit contains more labor than another similar unit does not make the first one of any more value to the consumer nor will it command a higher price. It is the desire of the employer, therefore, to have a uniform labor cost in each unit of product, which is possible only when he purchases output or useful work rather than mere labor.

Compensation.—To pay for work on the basis of results demands some means of fixing the compensation for each unit of output. In order to satisfy this demand, management has been obliged to experiment and grope about in search of a satisfactory answer.

Chapter II treats more fully of these early attempts and failures to supply this need and reviews the difficulties which were encountered in developing what is now recognized as the real solution—scientific time study.

Employees' Objectives.—The employee now recognizes the advantages to himself of working in a shop where modern time-study methods are used.

The principal objectives of the employee are to secure maximum earnings commensurate with the effort expended, while working, in so far as conditions will permit, in a healthful and agreeable environment. Time study has contributed immeasurably toward the attainment of these objectives for the employee, because thorough time-study analysis brings to light the undesirable and improper working conditions and methods and establishes a fair time value for every job. These time values, when used with a proper incentive system of wage payment, enable the employee to increase his earnings by increasing his output.

Employers' Objectives.—The employers' objectives are, briefly, to secure a maximum output of standard quality at a minimum cost per unit. Progressive employers recognize the proper application of time-study methods as being one of the most important factors in modern industrial management which tends to bring about the accomplishment of their objectives. Such obvious benefits to the employer as having a better-satisfied working force, resulting in a minimum labor turnover, and getting what he pays for are alone sufficient to command his cooperation and support.

Conclusion.—It is now clear that the necessity for measuring human effort was an economic development, which paralleled and was actually a part of our normal industrial growth.

CHAPTER II

AIMS, FUNDAMENTALS, AND DEVELOPMENT OF TIME STUDY

Chapter I has shown the desirable end, paying the worker, not for the time he spends at his place of work, but for what he actually accomplishes. The means to this end—the method used to determine the number of standard hours which will be allowed on any job—is time study.

Aims of Time Study.—If a number of experienced time-study men were asked to define the aims of time study, a few might thoughtlessly say: "To determine the number of standard hours in which an average man could do a given piece of work." The rest, being real time-study men, would say:

> To subject each operation of a given piece of work to a close analysis, in order that every unnecessary operation may be eliminated and in order to determine the quickest and best method of performing each necessary operation; also to standardize equipment, methods, and working conditions; then, and not until then, to determine by scientific measurement the number of standard hours in which an average man can do the job.

It is because time study aims to do more than merely set time values that it has gained for itself such an important position in modern management. Because of the elimination of waste of time, effort, and material and because of the speeding up of standard operations and processes used in production work by the close study and searching analysis that it involves, time-study work is now recognized by every progressive plant manager to be a leading factor in mass production, low costs, and efficient operation.

The Average Man.—Usually when a group of time-study men meet for a conference, the "average man" is argued about and discussed. Yet, if someone asked for a definition of an average man, very few would be able to answer, and in all probability, no two of these answers would be alike. The term "average man" has come to be used almost as loosely as has the term "efficiency."

For purposes of discussion, an average man may be defined as a man who has been working on a given class of work long enough to know it thoroughly, who is not unfitted for the work by nature, and who possesses normal intelligence and enough education to perform satisfactorily the work at hand. In general, about 30 per cent more is produced by the skilled worker than the average man when both are exerting the same effort under the same conditions. It must be borne in mind that an average janitor and an average tool maker are two different types, that the length of time necessary to learn a job thoroughly may vary from a few hours for a dipper in a paint shop to several years for a man engaged in assembly work on large electric locomotives, and that the figure 30 per cent, while holding good in a great many lines of work, may vary higher or lower in lines permitting or not permitting the development of a very high degree of skill.

If there is only about 30 per cent difference between the average worker and the skilled worker, how is it possible for one man to turn out twice as much work as another? This is because the two men differ in effort or application to work. If, for example, in a 10-hour working day a skilled worker devotes all his time to his work and if in the same day the average worker actually works only 6 hours and wastes the rest of the time, the difference between the output of the two men will be not merely 30 per cent which represents the difference in their abilities, but more nearly 117 per cent. During the 6 hours that the average man works, the skilled man will produce 30 per cent more, and in the 4 hours which the average man does not work, the skilled man will, because of his superior ability, produce the equivalent of approximately 5.2 hours as measured by the ability of the average man. This 5.2 hours is almost 87 per cent of the average man's total working time for the day, which when added to 30 per cent previously gained, makes a total gain of nearly 117 per cent. The skilled man not only excels the average man in ability but he also is able or willing to spend more of his time at his work.

Standardizing the Work.—It is of little use to establish a time value on an operation if the method of performing that operation is to be changed overnight. The operation must be studied, analyzed, and discussed from every angle before the time study is taken. Quite often the task of standardizing the methods of doing a given job will take much longer and will

require much more thought than the actual taking of the time study.

Some of the things which must be considered in standardizing work are labor-saving tools, jigs, and fixtures, most efficient cutting speeds and feeds, arrangement of the work bench, material-handling equipment, methods and motions used by the workman in doing the job, and working conditions, such as light, heat, and ventilation. All these will be discussed more fully later.

Changing Established Time Values.—Once a time value has been established on a job, it must never be changed as long as the conditions and methods in effect when the time study was taken still exist. In some cases, it may be permissible to raise a time value if the time-study man has obviously made a mistake in setting it and where the workman is not being allowed time for all the operations which he must perform. But if the error is in the other direction, the value must not be lowered. There is one possible exception to this rule and that is where the high time value is plainly due to a clerical error on the part of the time-study man. The management should not be expected to pay for such mistakes. When the time value is changed, the greatest care should be taken to show the man or men affected that a clerical error and not an error in judgment is being corrected. Correcting an error in judgment after a worker has brought it out by doing the work in much less time than that allowed is absolutely fatal to any incentive plan. Far better that the management stand the expense of a few time values wrongly made too liberal than that the workman lose faith in the fairness of the incentive system and get the feeling that he must restrict his output to a certain amount if he is not to have the rate reduced. The practice of cutting rates, unfortunately, was quite general in the early days of setting piece rates by guesswork, and there is a feeling in the mind of the workman that he will be allowed to make only a certain amount of money. Only by guaranteeing that a time value once established is permanent unless methods, tools, or design of the part is changed may the management expect to secure from the workman his hearty cooperation and best effort.

When a change in methods, tools, or design does occur, the operations affected by the change should be retimed and the time values changed to suit the new conditions. The change should

not be used as an excuse to change unaffected time values which may be a little too high.

Inspection Requirements.—The time-study man, before he makes a time study of a job, must first become familiar with the inspection requirements. He should find out from the inspector just what will be required in regard to finish, fit, dimensions, and the like. By this, the time-study man will know whether an operation is necessary or unnecessary and whether the workman is doing the job poorly or too well; in short, he will be able to prevent the workman from doing too much and thus wasting time and effort, and he will see that the workman is allowed time enough to do all that is necessary. The time-study man, however, does not determine quality.

When studying a job that has already had work done upon it, the time-study man must check the inspection requirements of the previous operation to make sure that the condition of the job is what it should be. This will prevent the man who is being timed from getting a time value for doing or finishing an operation for which allowance has already been made.

Beginnings of Time Study.—The above principles of time study were not always known nor did they just happen. They are the result of a great deal of development work extending over a number of years.

When the idea first occurred of paying a man for what he does, the question at once arose, "How is the management to determine how much a man can do in a given length of time in order that it may know what to pay him?" This was answered by assuming that this amount could be determined best by the man who knew most about the work. The duty of establishing time values or piece rates was given in most cases to the foreman in charge of the work. It soon developed, however, that these men had little to guide them but judgment and that in many cases their judgment was incorrect. They knew "how" and "why" but not "how long." In addition, the tendency of a human being to be influenced by his own likes and dislikes was noticeably present. One man's opinion of the honesty and ability of another man was a decided factor in the setting of time values. The foreman, in general, considered the setting of time values as secondary in importance to his other work. When a workman approached a foreman whose mind was occupied with production problems to ask for a time value for a job, the value

was often given without much thought. Under this system, a great many time values were necessarily very inaccurate. They were either too low to enable the man to earn a fair day's wages or so high that the management felt that earnings were too high and accordingly cut the rate. This led to dissatisfaction and ill feeling on all sides.

The Overall Check.—Out of this chaos of guesswork, a new method arose. In large organizations a new department was created and in small ones a new job was born. This department in some plants was known as the rate-setting department and the men in it as limit setters or rate men. These rate men were chosen on the basis of their skill in and knowledge of the work and for their general intelligence, because it was still felt that a man must be an expert at the work to set time values. These rate men differed from the foreman in that their only duty was that of establishing time values.

The rate man, in some cases, estimated the time value for a job to be performed from a drawing of the part. He analyzed the work and determined to the best of his ability, which was by no means constant, what was required and how the job should be done. From the knowledge thus gained, he estimated the time value.

In other cases, he actually watched the job as it was being done and noted the length of time required to do a number of pieces. The time value was established by adding to the average time any allowances which the rate man felt were justified. Under this system, the man could extend the time for doing the work in a number of small ways which the rate man could not readily detect. Then, too, the rate man used himself as the standard when judging others, which was only natural. The inconsistencies which resulted were many and serious and led to a great deal of suspicion and mistrust. High earnings were made which were out of proportion to the increase in production. The rate man, seeing this, became suspicious and lost confidence in both the workman and himself and acted accordingly. The workman as a matter of self-protection resorted to any means through which he could extend the time of doing the job while being checked. As a matter of principle, he fought every time value set whether it was good, bad, or indifferent.

And all this time, the necessity was growing for a better, fairer, and more accurate method of establishing time values. To this end time study was developed.

Introduction of Time Study.—Dr. Frederick W. Taylor has many times been referred to as the father of time study. He was responsible for the introduction of the fundamental principles of time study, and it was largely due to his efforts and his faith in this work that time study withstood the criticisms and antagonisms of old-school pessimists and finally won the recognition which it deserved. Scientific time study as it is now known has been developed upon the foundations laid by Dr. Taylor.

The value of time study was not fully recognized at the start and was generally opposed by both employer and employee. The employer did not see how anyone, seemingly unfamiliar with the conditions existing in his shop, could with a stop watch correct the inconsistencies which his foremen with their years of experience had been unable to control. They judged time study from the surface only and did not investigate the underlying principles.

The opposition of the employee was a little more justifiable. For years he had suffered from various attempts at time setting, and he had no reason to believe that the new method would be any better than the old ones had been. The stop watch appeared to him as an inhuman device for reducing him to the status of a machine, and it was no easy task to convince him that time study would work to his own advantage. He was convinced, however, and now, where a group of men have been working under a good incentive system based on time study, it would be very hard, if not impossible, to get them to go back to former methods. They realize that they get fair treatment and justice under the time-study system, and they know that they have the opportunity to earn all that their abilities will permit without fear of a reduction in time values.

Spread of Time Study.—As time study began to be known, the more progressive employers went more deeply into the subject and soon began to realize its possibilities. They saw that time study would conserve their diminishing labor supply and that it would bring about the training of better workmen. When these employers had used time study for a while, they began to forge ahead of their competitors because of lower costs and greater efficiency. To meet this, the other employers had to fall in line.

The more time study was used, the more uses were found for it. Its application was broadened daily until now there are few jobs which cannot be placed on an incentive basis by the use of time study.

CHAPTER III

QUALIFICATIONS OF A GOOD TIME-STUDY MAN

To be a good time-study man, one must be able to carry out the aims, principles, and practices of time study and to get the desired results with the least amount of friction and discord. In a plant where time study has been long established, this is a comparatively easy task, but where the idea is new to both men and management, there is sure to be a certain amount of antagonism and criticism. It requires a high-grade man to handle a situation of this kind successfully, and it will be useful to fix firmly in mind the essential characteristics that such a man must have.

Personality and Tact.—A good personality is necessary for success in nearly any line, and this is markedly so in time-study work. A time-study man must first, last, and at all times be able to get along with people in a positive way. Many men get along by simply keeping still and giving in to the point of weakness. This is the negative way. The time-study man must be able to hold his ground when he feels that he is right and to gain his point without losing the cooperation and good will of those opposing him. He must be able to establish new methods without hurting the feelings of those who originated the old ones. He deals directly with the workman through the most sensitive point of contact—the pay envelope. He will meet with obstacles on every hand; yet he must put through that which he believes is right and, at the same time, make his work pay dividends.

To do all this requires tact, sympathy, and an understanding of the wishes and desires of those with whom he is working. He must have a real interest in his fellow men and be guided by a practical conception of the limitations of human nature. Only a man possessing these attributes can hope to accomplish the work of a time-study man in the most satisfactory manner.

The time-study man must in addition have no little sales ability. In almost everything he does, he is performing the function of a salesman. He is selling the idea of time study to the management, selling new methods to the shop supervisors,

and selling time values to the workmen. And selling in its true sense does not mean forcing something on an unwilling customer but rather in showing the customer his need for the thing, creating his desire for it, and then furnishing him with it.

Patience.—A time-study man must possess that most desirable virtue—patience. He must be able to see the fruition of his plans withheld again and again, he must experience trying delays, he must be able to talk calmly to excited and angry men, he must be able to experience lack of cooperation and to withstand criticism, all without losing his equilibrium. A time-study man must have the respect of the supervisors and the workmen with whom he deals, and no other single quality will do more towards securing this respect than the ability to keep his temper under control. One who loses his temper when approached by an angry man loses a decided advantage and deprives himself of his most formidable weapon—his poise.

Judgment and Self-confidence.—A good time-study man needs better than normal judgment. He must keep his head during a heated discussion in which others are excited and a little irrational in order that he may be ready to pass calm and impartial judgment on the subject under discussion. He will be called upon frequently to determine the intrinsic worth of new ideas and suggestions. He must be broad minded and open to conviction, he must be able to view a moot question from every angle, and he must possess the faculty of basing his conclusions upon the merits of the case rather than upon the influence of preconceived prejudices.

Above all, he must be able to judge men. He must size them up and sense whether or not they are honest with him. If they try to slacken their efforts during a time study, he must realize it and must be able to tell the degree of skill that each man possesses. And always, in exercising his judgment, he must strive to be fair minded and to keep his sense of proportion.

Confidence in himself and his work is essential to a time-study man. New ideas meet with strenuous opposition from unprogressive or ultra-conservative men, and unless the time-study man has this confidence, gloomy predictions and hindering actions are very likely to worry him and bring doubt into his mind. Once a man begins to doubt himself in the face of opposition, his cause is lost, but let him keep his poise and self-confidence and the battle is won.

Education.—One of the important requirements for a time-study man is that he have at least a high-school education or its equivalent. This equivalent may have been obtained right in the shop, at night school, or through correspondence courses. In addition to academic training, the more shop experience a man has the better, for it helps to balance his perspective in a way that cannot be accomplished by theory alone. A time-study man should be grounded in the fundamentals of algebra and English, for without these he cannot hope to derive formulas or to express himself clearly in his instructions and reports. Any other study which provides mental training and teaches one to think and reason for himself will be helpful. The more mathematical training a man has the better, for this will be invaluable in all formula work.

The college man has the advantage of a more thorough academic training, but if he is a recent graduate, he will need some shop experience to give him more of the practical viewpoint. He will need to be able to use shop terms and talk a common language with the workmen in order to gain their respect for his knowledge and ability. For these reasons, it is better to give a college man a few months on the shop floor where he can associate with the workmen as one of them before starting him in on time-study work.

Mental Traits.—A good time-study man should have, primarily, an analytical mind. Time-study work requires constant analysis, constant dissecting of systems, methods and processes, and the viewing of each element separately. The time-study man must be able to go directly to the bottom of every problem and determine the reasons for conditions as they are. He should have a naturally inquisitive mind and a desire to pry into and learn everything connected with his job.

The time-study man must be alert and always on the lookout for new ideas and improvements. He should have originality and a naturally inventive turn of mind so that he can work out new and better methods for doing things. He must, first, recognize the problem and then solve it.

To be a success at his work, a man must like it. Since the time-study man's mental work is largely that of solving problems, he must like to do this. Every unsolved problem should present a challenge, and the harder the problem the more eagerly should he accept the challenge. He should go at a problem, seemingly

impossible of solution, with all the zest of a football fullback hurling himself at a hitherto unbroken point in the line.

Accuracy.—A time-study man must be accurate in everything he does. He must judge accurately, reason accurately, and observe accurately. He must be accurate in taking and working up data and also in applying these data in setting time values. If the time-study man errs in any of these details, his final results are likely to be far out of line with what is to be expected. If a worker receives a time value which is noticeably incorrect, he is likely to lose confidence in the time-study man. It is possible for one mistake to destroy that which it has taken months to build up, that is, the confidence of the worker in the fairness and the ability of the time-study man.

Initiative and Optimism.—A time-study man must have initiative. He directs his own efforts to a great extent and works out his own plan of action. He has no one to go to for definite instructions as has the man on a more routine job. Sometimes he may be shown a certain piece of work and asked to study it. More often he will have to see the possibilities of a job and will have to tackle it himself. Unless he has the initiative to go ahead and start things moving himself, he will not make much of a success of his work.

A time-study man should be a born optimist. Every day in his work he runs into so many pessimists and doubters that his spirits will soon be dampened and his ardor cooled unless he resolutely ignores the gloomy predictions on all sides and proceeds confidently on towards his goal.

Finding a Time-study Man.—Two large fields may be searched for time-study men by a plant which is fortunate enough to have a trained man ready to head time-study work and to teach new men the proper methods of procedure. The first place is right on the floor of the plant itself. There are almost certain to be several men anxious to get ahead, willing to study and work hard, who possess enough of the above qualifications to do time-study work. These men have the decided advantage of knowing conditions as they exist in the plant and of realizing the viewpoint of the workman. They are practical men and have a thorough knowledge of the work they are to study.

The other field is among recent college graduates. They have the advantage of broad education and a mind trained to reason. They lack, however, practical background, and it is for this

reason that it is best for them to spend a few months doing actual productive work before going into the time-study department. From the viewpoint of the college man, time-study work gives him the opportunity of getting in a quick and thorough fashion that which he most needs—experience.

Conclusion.—A perusal of these qualifications may give the idea that a time-study man must be a kind of superman. Perhaps he should be, but he undoubtedly will not be. It would be hard indeed to find a man possessing all these qualities. The conclusion, then, is that there are no good time-study men. That is by no means true. There probably are no perfect time-study men, but there are many, many, good ones. These good ones have a certain amount of the above qualifications and have tried to cultivate others as best they could. The result is that they are striving to do their work conscientiously the best they know how, and they are building up and maintaining the good reputation of time-study work throughout the country.

There are several things that make time study the interesting and fascinating work that it is. No work which does not present obstacles to be overcome can long be interesting. The time-study man finds two conditions which at first may prove stumbling blocks on the road to results. All new ideas and improvements, no matter how good, meet with a certain amount of opposition. All changes are at first resisted. This is the first obstacle. The other is the odium attached to any incentive plan in the minds of the workman, a heritage from the era of guesswork. This is rapidly being overcome and, when time study becomes generally seen in its true light, will disappear altogether.

Time-study work itself presents many and varied problems, each of which must be solved as it comes along. No two problems are alike, and this prevents time-study work from becoming routine and hence dull. There is always a chance for new and original thinking. Then, after the time-study man has overcome his obstacles and solved his problems, he has the satisfaction of seeing his plans bear fruit. He sees his suggestions adopted and his predictions of savings actually being fulfilled, and while the commendations of the management are yet ringing in his ears, he is called out again to exercise his wits and ingenuity on another job, perhaps still more engrossing.

CHAPTER IV

ELEMENTS OF TIME STUDY

It has been said previously that time study means considerably more than the mere recording of elapsed time during the performance of a piece of work. It is the intent, in this chapter, to

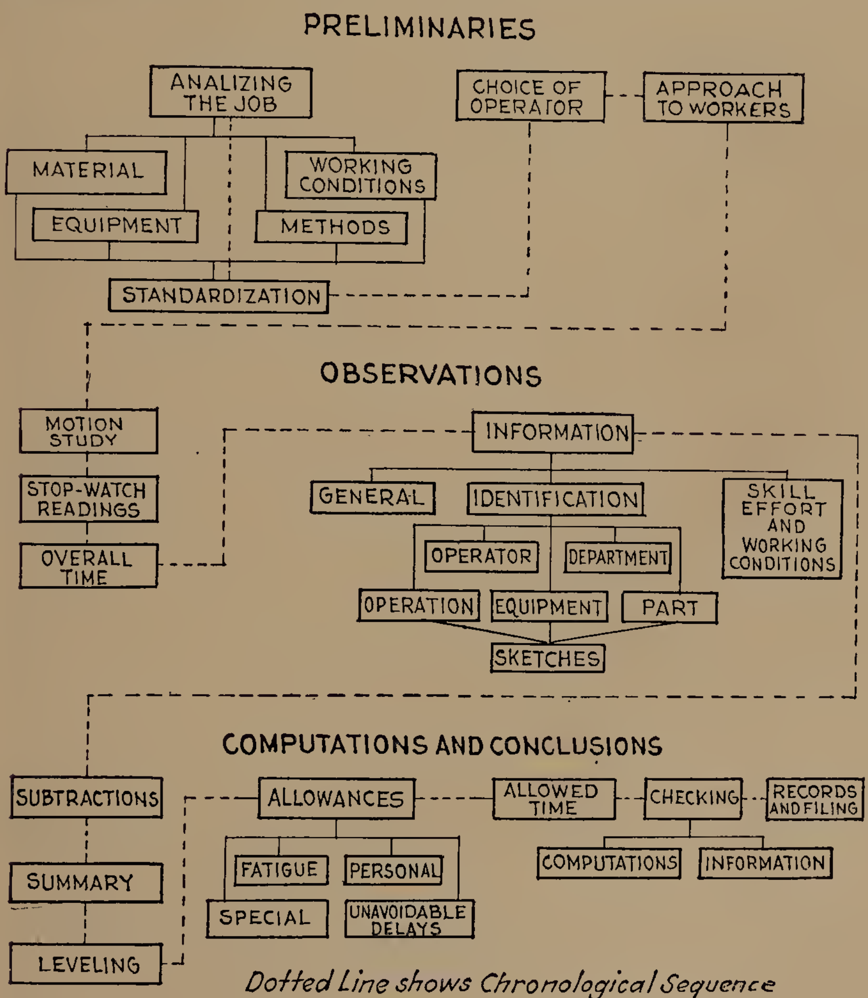


Fig. 1.—Graphic analysis of the elements of time study.

present a composite picture of what is involved, to describe briefly the different steps essential to the making of a good time study,

and to show their relation to each other and the order in which each should be considered. In Fig. 1, time-study procedure is analyzed graphically into its various elements, each of which is treated briefly in this chapter. Each of the more important elements is also given a subsequent chapter devoted exclusively to a full and complete discussion.

Analysis of the Job.—The proper consideration of this subject is essential. The analysis of the job is a thorough study of existing conditions, methods, equipment, and anything else that might affect the time required to perform the work satisfactorily. It also demands that the time-study man familiarize himself with the physical characteristics, application, and inspection requirements of the part or piece of apparatus upon which the operation is being performed. Analysis of the job has a decided influence upon the ultimate results. If done properly, it will simplify greatly the work to follow and facilitate the successful application of the time value which is determined by the study.

Standardization.—All this analysis and study of the factors influencing the performance of the job is made with a view toward standardization, another very important preliminary to the actual time study. It is practically useless to start taking studies or setting time values until the job is standardized. Using a production job as an example, this condition may be defined by saying that the job is not standardized unless each piece is delivered to the operator in the same condition, and it is possible for him to perform his portion of the work on each piece by completing a set cycle of motions by doing a definite amount of work with the same equipment and under uniform working conditions. Once this standardization is effected and found to be workable, the time value is established accordingly, and it is reasonable to expect the operator to do the job within the allowed time by continuing to follow the prescribed method.

Choosing the Operator.—Very often there is only one operator employed on the particular job in which the time-study man is interested. In this case there is no choice, but whenever the time-study man has the opportunity of making a choice where several operators are doing the same work, he should, of course, select the one from whom he can expect the best results. It is of considerable assistance to have the confidence and cooperation of the operator, and an operator who has this attitude towards the time-study man is always a desirable one to study. Intelli-

gence breeds understanding, and understanding of time-study principles by the workman generally commands cooperation. Hence, it is well to study the more intelligent operator. He can be reasoned with and is more likely to receive favorably the time-study man's suggestions to experiment with new methods or ideas. He may make some good suggestions himself. The operator selected should be thoroughly accustomed to the method of doing the work so that he will proceed from one operation or motion to the next without hesitation or delay in an efficient and systematic manner. The operator who likes his work and has a reputation for doing good work is usually a good choice, for he doubtlessly has analyzed the job to a certain extent himself.

Other advantages being equal, it is more desirable to make the study on the work of the more skilful operator, not because a minimum performance time is to be secured but because the more highly skilled man is also more consistent and more systematic. His skill is, of course, taken into consideration when the leveling process which will be described later is used. It is not good policy to study an operator who has an antagonistic attitude toward time study, if it can be avoided. If there is no better choice, an effort should be made to convert the antagonist before proceeding with the study. This is often accomplished by explaining the purposes and fairness of time study.

Ordinarily, judgment is passed on the merits of a worker, in a very general way, by saying that he is above average, average, or below average. This classification conveys some idea of relative ability, but when one stops to analyze what is really meant, he finds that such a description is inadequate because no workman is, or should be, judged on the basis of any single characteristic, but rather on the basis of all the characteristics which influence his ability as an operator. These characteristics are mainly as follows:

Attitude: feeling towards work, fellow workers, and company.

Conduct: attention to work.

Dependability: attendance, punctuality, and reliability.

Intelligence: judgment, resourcefulness, and ease of learning.

Performance: quality and quantity of work, waste, and broken tools.

Physical qualities: physique, health, and strength.

It will be readily appreciated that a worker can be above average, average, or below average in any one of these characteristics.

and it is necessary that the time-study man should consider all of these details or as many of them as possible in choosing the operator.

Approach to Worker.—An inexperienced time-study man frequently makes the mistake of antagonizing a worker simply by his method of approach. It is part of a time-study man's job to gain the confidence and good will of the workmen. He cannot be successful in this if he treats them indifferently. They do not appreciate being regarded as a part of the machine which they are operating; yet a time-study man apparently does just this if he calmly walks up with his watch and begins to record readings without offering any comment or explanation which would tend to create a friendly spirit of mutual interest. It is well to explain to workers who are not accustomed to working under observation the methods and purposes of time study. Often they do not understand that it is of no advantage to them purposely to introduce delays and unnecessary operations. It should be made clear that such things are not included in the allowed time and that they merely complicate the study. Operators generally misinterpret the motives of the time-study man when he selects the skilled man for his study. They are inclined to feel that the allowed time will be based upon that man's performance, thus making it very difficult, if not impossible, for the average man to do the job in the time given. This is, of course, erroneous, and they should be made to understand that the leveling method of determining values enables the time-study man to arrive at the correct time regardless of the speed and the skill with which the operator works.

It is helpful to a time-study man, when determining his method of approach, to try to place himself in the position of the worker and to ask himself what he would expect from a time-study man and how he would like to be treated. There is no excuse for the feeling of suspicion and mistrust that sometimes exists between observer and worker. Human nature, after all, is pretty much the same everywhere, and workers, like everyone else, will generally respond favorably to an open and frank method of dealing with them. Nothing will command their respect and their cooperation more than a realization that the man with whom they are dealing knows his business. In order to create this impression, the time-study man must be able and willing to discuss intelligently the practical, as well as the theoretical,

phases of the work. One of the many reasons for proper analysis of the job is here apparent.

Motion Study.—If a job has been properly analyzed and standardized, the sequence of motions will have been given some consideration. This, the first step in actual observation, is worthy of close study; it draws upon the knowledge and judgment of the time-study man more than might at first be supposed. He is obliged to define exactly in a very few well-chosen words and in a limited space on the time-study form every motion and detailed operation performed by the worker. This demands familiarity with technical as well as practical shop terms, and a knowledge of the proper application, manipulation, and nomenclature of the machines, tools, and equipment used. The breaking up of the job into its elemental motions must be clean cut and sharply drawn, so that when the watch readings are being recorded, the chance of one element overlapping the next will be minimized. It is sometimes advisable to make a preparatory line-up of the sequence of motions. Some thought can then be given to the best arrangement on the time-study form so as to be the most economical with space and to facilitate the recording of watch readings. If the detailed motions are described and lined up properly, one who is familiar with the line of work would be able to visualize every step by merely reading over the list, although he had not actually seen the particular job performed. The information should be so specific that a competent operator could use it as instructions for doing the job even though he had never performed the operation before.

Stop-watch Readings.—The recording of watch readings is regarded by many people as the principal feature of a time study. The importance of accuracy at this point is paramount and must not be slighted in the least. Without correct watch readings, all else is useless.

Much of the success of time study depends upon the preparatory steps that have been discussed thus far. They call upon the highest qualifications of the time-study man, qualifications without which he cannot be a good time-study man. Yet, here, when one comes to the actual technique of time study, he finds that the principal if not the only major requirement is accuracy. Anyone of normal intelligence who can concentrate can quickly learn to record watch readings; yet he may never be able to qualify as a good time-study man. All that goes before is in preparation

for the observations, and all that follows is based upon the data secured at this time. The vital importance of accuracy should now be apparent.

The foregoing must not be construed to mean that the work of taking observations is easy. To stand in one position with attention fixed simultaneously on a stop watch and on the hands of an operator for several hours is a physical strain. It is also a mental strain to concentrate on the job when surrounded by disturbing influences. It is not difficult to acquire the necessary skill to record observations, although this requires practice. Concentration must be developed to the point where it becomes a habit. The principal difficulties encountered are foreign operations, variations in sequence, and a number of successive short operations which make it necessary to remember the readings until the occurrence of an operation of sufficient length to allow time for recording them. Practice will develop the skill needed to meet these irregular situations without affecting the accuracy of the observations.

Overall Time.—The starting and stopping times of the study as shown by the ordinary watch should always be recorded. From this the overall elapsed time for the duration of the time study may be readily computed. It should be equal to the sum of all the detail times, foreign operations, and delays, and when divided by the number of pieces completed, will show the average overall time for each piece. This overall time is valuable as a ready check on performance during the study, but it should not be allowed to influence the determination of the allowed time, because it includes everything that occurs during the course of the study.

It is sometimes desirable to know the actual overall time on each piece in order to check the general consistency of the worker. When this is wanted, ordinary watch time should be recorded at the completion of each piece.

Information.—A time study, to be of value for future use, must tell the whole story of the job in such a way that it will be understood by anyone familiar with time-study methods other than the observer who might have occasion to refer to it 6 months or a year later. This will not be possible unless all identifying and other pertinent information is recorded at the time the study is made. Provision is made on the back of the sheet for such data. Records should be made to show complete identifications of the

operator, the part or piece of apparatus, the machines, tools, and equipment used, the operation, and the department in which the operation was performed. Sketches, for which space is provided, are generally a desirable and satisfactory adjunct to verbal descriptions. Note should be made of the effort given and the skill exhibited by the operator, of working conditions, and of anything that is peculiar or relevant to the job.

Subtractions.—This step in time-study procedure is just what its name implies. If the continuous method of recording watch readings was used when the observations were made, it is only necessary to subtract successive readings to determine elapsed times. This is simply clerical routine and may often be delegated to a clerk who can be depended upon for accuracy and who understands how to take care of foreign operations, variations in sequence, and other irregularities in the recorded observation.

Summary of Elapsed Times.—After abnormal values have been discarded, the results of the subtractions—the detail time values—are summarized in an ordinary manner at the bottom of the sheet in preparation for the determination of standard detail values. A detailed explanation of the methods of making a summary is given in Chap. XII.

Leveling.—It is now necessary to select or derive the proper time value for each detail motion or operation in the study. This must be done from the summaries which have been made. When it is considered that the detail values often vary over a fairly wide range, sometimes as much as 100 per cent for short operations, it will be appreciated that this task must be approached with careful thought and sound judgment. At this stage skill, effort, and working conditions must be taken into account. Obviously, no general rule can be laid down which can be applied in all cases. The human element becomes a dominant factor at this point because no two operators are consistently, if ever, of exactly equal ability. If all workers available for time study were average—no experts and no dullards—the problem would be greatly simplified. It must be remembered that time-study work is subordinate and an aid to the main business of production and must never be an obstruction. It must not require the creation of special or unnatural conditions but rather must be flexible enough to fit in with the general scheme of modern industry. The time-study system must be applicable to all operators, good, bad, or indifferent. The work must go on

whether the most desirable type of operator is to be found or not. There must be, however, a leveling process at some stage of the work. The time-study man must be able to arrive at a proper time value no matter whether the subject of his observations is a good or a mediocre operator. The time required by a poor operator must be graded down, and the time required by a skilled operator graded up so that the final result is a reasonable allowance such that it can be met by a worker giving average performance. The skilled man will, of course, benefit by his greater production, and the untrained operator will be unable at first to meet the allowed time.

Much has been written and said about proper methods of determining standard time. Some authorities advocate simple averages, others offer methods based upon consistency and length of operation, and still others merely advise the use of judgment. Simple averages are unsound because they do not take into account skill and effort. Consistency and length of operation combined indicate a little more research and theory but are not reliable because an expert operator can fake consistency to the point of deceiving an experienced observer. Broadly speaking, judgment is too general and indefinite and, unless guided, has too wide a range to be relied upon. Guided judgment, however, must play an important, if indirect, part in leveling.

Allowances.—Since the derived time values are net elapsed times, they do not provide for delays and other legitimate allowances. Something, therefore, must be added to take care of such things as fatigue, personal needs, delays outside of the control of the workers, and special or abnormal conditions of the job. Some of these allowances, such as those for fatigue, vary according to the nature of the work, and flat percentages must be determined for each general class of work, such as bench work, machine tool operations, hard physical labor, and so on. The standard time is then increased by the percentage applicable to the class of work in which the element falls. Personal allowances are the same for all classes of work. Peculiar conditions surrounding specific jobs sometimes demand special allowances.

Allowed Time.—The allowed time is the ultimate objective of an individual time study and should be a fair allowance for performing the job. It should represent the time which an operator of average skill would require when making an average

effort under average working conditions and when experiencing the retarding effect of fatigue, unavoidable delays, and the like. Jobs requiring a set-up of machines or other equipment before production work can actually begin should be given an allowed time for the set-up and first piece and then an allowed time for each additional piece.

Checking.—Before the allowed time is placed on record, the time study should be thoroughly checked for accuracy in computations. The allowed time checked against the average overall time for each piece should disclose any very flagrant discrepancies, and will show whether the operator met the allowed time during the study, but this is not to be interpreted that allowed time must always exceed the average overall time. This comparison is only a general guide which should be used advisedly. The completeness of information should also be closely checked. Many studies are rendered valueless for future use merely because the job is not specifically identified and fully described.

Records and Filing.—All time studies and related data should be filed so that they are readily available for reference. Either the workman or the management is likely to wish to discuss a time value at any time, and the time-study man must have his data on hand so that he can answer all questions and justify any stand he may have taken.

The allowed-time values, as determined by time study, should be recorded and filed in a convenient manner for the use of time clerks or supervisors. A card index, filed according to numbers which identify the part, is generally found to be most satisfactory as a working file. A permanent official record should also be kept from which duplicate cards may be made out for the working file as the active ones become lost or soiled.

CHAPTER V

ANALYZING THE JOB

Analyzing the job means more than the words might imply to the layman. It means, in a broad sense, analyzing the job and everything required for the performance of the job, such as materials, tools, method of procedure, and working conditions. It means segregating the job into its component parts, comparing methods and similar work, and determining the reason for and the importance of each operation.

It is a good policy never to be suspicious nor to question the honesty of an operator. The time-study man should neither credit nor discredit effort according to his belief in the fairness of the operator. Rather, he should be so equipped with knowledge pertaining to all the details of the work to be studied that he can definitely decide the kind of effort from the evidence at hand, regardless of his belief as to the operator's honesty. Only in this way can a time-study man have the confidence and respect of the operator and establish consistent time allowances.

The necessity for a practical knowledge of proper tools for performing a given operation, of the correct handling and use of these tools, and of proper working conditions can hardly be exaggerated. Without this knowledge, the time-study man cannot be expected to analyze any job with a view to determining and establishing the most efficient and systematic method of performance. The success of a time-study man will depend largely on his analytical ability and the amount of this practical knowledge which he possesses.

Purpose of Operation.—Before one can successfully pass judgment or determine the best and most efficient way to perform a given operation on a part, he must know why the operation is being done and the function which the part will fulfil in the ultimate use and application of the finished product. It would be entirely unnecessary to put a high-grade finish on something that will eventually be hidden away in an automobile or some other piece of apparatus as long as this finish is not necessary to

efficient and lasting performance. A plasterer does not attempt to distribute the rough plaster on the walls of a house as evenly or as smoothly as he does the finish plaster. A painter does not take the time or the care in painting preliminary coats that he does in painting the finish coat and the trimmings. In a home, an ordinary floor made to be covered with a rug does not call for the same workmanship as does the hardwood floor of a ballroom. Electric controllers used on elevators in large department stores and hotels usually have an ornamental design and finish; on the other hand, those used in steel mills and similar places require a more rugged construction and finish to protect them from the rougher usage to which they are subjected.

The time-study man should know when a part being machined is to have a running fit or a driving fit, a contact surface or a surface merely smoothed up for appearance. He should know the effect that a close or a loose fit will have on the performance of the apparatus. He should know if the operation is preliminary to some other operation, as in the case of a rough turn for a grinding operation. In general, the time-study man should know the reason for every detail operation being performed and its effect in the ultimate use and success of the product. He will then be able to make suggestions intelligently toward improving the product, eliminating unnecessary operations, and facilitating necessary work.

Inspection Standards.—After the time-study man has satisfied himself as to the purpose of the operation, he should go to the inspector and find out just what are the inspection standards. The inspector must also have some knowledge of the purpose of the operation. He should set his inspection standards from this knowledge plus the engineer's specifications rather than from the specifications alone. Then, for example, if the specifications call for a $\frac{1}{2}$-inch diameter on a certain shaft, the inspector will know whether to hold to this dimension within a few thousandths or whether a variation of $\frac{1}{64}$ inch is allowable. The inspector and the time-study man will work together in determining such permissible allowances and will act as a check on each other in determining the standard method for doing the work.

If the piece is to be inspected immediately after the operation has been performed, the time-study man will familiarize himself with such requirements as finish, dimensions, tolerances, and allowances. If the piece is to have one or more subsequent

operations performed on it before reaching the inspector, the time-study man should learn the final requirements. Then he should study the subsequent operations in order to learn how they fit together as a whole to make up the finished product. He will learn the part played by the particular operation he is about to study in bringing the product toward the finished state.

Often this analysis will result in changes and savings, and many times an operation may be eliminated or combined with another. For example, a time-study man is about to study a milling operation on a small casting. He learns that, after milling, the part is taken over to a bench where the burrs left from milling are filed off. Later, during his study, he notices the operator of the milling machine has several minutes while the machine is making the cut during which he has nothing to do. From his previous analysis, he sees at once that this operator can do the filing during this idle time and thus eliminate the next operation. If he had not first made a careful analysis, this possibility would have passed unnoticed.

Knowledge of inspection requirements will also enable the time-study man to be certain that the material or part is delivered to the operator in the proper condition, and that he performs all the necessary, and only the necessary, work upon it.

Materials.—All materials should meet required specifications as to physical properties and conditions. All abnormal conditions, such as castings being extra hard or defective due to improper molding or bar metals being oversize, unusually tough, or crooked, should be traced to the cause and an attempt made to bring about a correction. Excess material on castings over that necessary to insure the required finish should be eliminated if practicable from a foundry standpoint. The reason for excess material in any place over that required for the proper making of the part should be traced to the source, and suggestions made to eliminate it. Such a condition not only makes the operation longer without improving the finish of the product, but it also causes a great waste. In the case of castings, it is not uncommon to have to remove $\frac{1}{2}$ inch of material in machining where $\frac{1}{4}$ inch would have made a perfect job with fewer cuts. This same condition may be found in the machining of parts from bar stock, or in making parts in woodworking shops. In fact, it is a condition which may be looked for in almost any line of industry.

In assembly work, punchings, machined parts, molded parts, and parts made by hand should be accurate and according to specifications. It is necessary to keep all fitting, filing, and adjusting down to a minimum in order to insure a better product and a greater output in less time.

Materials such as oil and cutting compounds for machining or sand for molding, which are used in the making of parts or the performing of operations, should be suited to the nature of the work. It is necessary to use a fine sand in making aluminum castings, but it would be wasteful to use this same sand for some brass alloys because of the additional venting that would be involved. In general, anything about the material used in any operation which causes unnecessary extra work should be determined and corrected before establishing a standard allowance.

Preparation and Development.—At the beginning of every job, there are always operations which will not occur on the additional pieces after the set-up and method have been established. This work consists of reading the drawing or the instruction card where these are used, getting all tools and materials required, making the set-up, such as putting dies in hammers or presses, and making trial pieces until final adjustments are made. A complicated set-up on a turret lathe, setting stops by trial cuts and locating dial positions, arranging tools and equipment for a bench operation, and making templates are all considered as set-up operations. Whatever the nature of the work, there will always be a certain amount of preparation work required, and in most cases, the ease and the efficiency with which the work will be done depends largely on this preparatory work. The time-study man must recognize this fact and should analyze the set-up thoroughly, having ever in mind the idea of improving and simplifying the operation with a resultant saving in time and improvement of quality. Any work which will be required to get the job started each time it is done should be considered as a set-up operation.

When a job appears in the shop for the first time, there is usually a certain amount of experimental work necessary to develop the best method for doing the operation. The time and thought given to development on work of a repetitive nature will be well paid for, and after the method is worked out, it should be recorded in order to eliminate the necessity for going through the same thing again on the same or similar jobs. The time

spent by the operator in the development of an entirely new job should preferably be paid for as day work. By this is meant any work which will not have to be done again each time the job comes through.

Method of Procedure.—Probably the most important part in the performance of any job is the method of procedure, and it is in this part of the analysis that the real worth of the time-study man will be revealed. It is usually found that where time study is not used, each individual does his own work according to his own ideas and, in most cases, never stops to consider whether or not the method can be improved upon, being satisfied with the fact that the finished product meets requirements. The argument is often advanced that every person has his own way of doing things and that it matters not how a job is done as long as it is done. It is absolutely true that people have their individual peculiarities and ideas, but this is no argument against the advantages to be derived from standardized methods.

It is not uncommon, where there is more than one workman engaged on a given operation, to find a difference in output which is often as much as 100 per cent. This is generally believed to be due to a difference in ability. Of course, this is partly true but not to the extent that it is thought to be. A thorough analysis will often show that different methods are being used and that the operators who are turning out the greater production are not expending so much energy as those turning out the lesser production. The former work with their heads as well as their hands and consequently have developed a smooth systematic method of procedure. It is altogether possible to instruct the less efficient operator to follow the same method, thereby increasing his output to such an extent that the greater part of the difference between the operator having the higher efficiency and the one having the lower efficiency is eliminated.

It is not to be expected that the time-study man, by observing the different operators engaged on the same class of work, will find one who is perfect whom he may use as a standard by which to judge and instruct the others. He will, however, find that in many cases one operator will have developed a method for doing a certain element of the operation that is easier and faster than the method used by his fellow workers. One of the other operators may have perfected a different element of the operation and so on. By discovering these differences through analysis,

the time-study man is able to combine the best methods for doing each element into one standard method of procedure for doing the whole operation.

Machine, Cutting, and Hand Tools.—All tools should be the most efficient available for any given operation. An operator should not be permitted to perform an operation by hand that can be done better and in less time on a machine. He should not use a smooth file when a rough one would do just as well, for with a rough file he will accomplish more work with less expenditure of energy. Files, chisels, saws, and the like should not be used after they have become dull. They should either be exchanged or sharpened, as they cause hard work with little actual accomplishment. Hammers should be of proper style and weight for the purpose, and layout tools should be in good condition and suitable to the work.

Special labor-saving hand tools should be used whenever a saving in time would result. Examples of these are socket wrenches, ratchet wrenches and screwdrivers, air drills, air hammers, air chippers, and air rammers. A striking example of what can be accomplished by the use of special hand tools occurred in the operation of mounting a piece of apparatus on skids preparatory to crating for shipment. Four bolts are used in mounting, and in running on the nuts an open-end wrench was formerly used. It was impossible to make a complete circle due to obstructions. The workman had to make a part turn, take a new hold, and repeat this until the nut was tightened. The substitution of a ratchet wrench for the open-end wrench reduced the time for the mounting operation by about 60 per cent.

Cutting tools used on machines should be properly ground and should have the correct clearances and shapes. Machine tools and all driving equipment and belts should be in good repair. The time-study man should determine whether or not the work is being done on the machine best suited to the job being studied. No job should be done on a No. 1 milling machine that could be done better and faster on a No. 4 milling machine, nor should a job be finished on a milling machine, lathe, or boring mill that could be worked to an advantage on a grinder, or *vice versa.* An engine-lathe job should not be done on a turret lathe, nor a turret-lathe job on an engine lathe. In analyzing the tools used on a job, the time-study man may find that the operation could

be segregated to advantage, *i.e.*, part of it could be done on one machine and part on another with a resultant saving in time.

For example, in the machining of cast-iron bushings, the elements of the inside and the outside surfaces must be parallel. It is very hard to get this condition on a turret lathe. Nearly true surfaces may be gotten if the set-up is carefully made by an expert, but even then there will be some variation between the individual pieces, and the results are neither dependable nor satisfactory. For these reasons, it was formerly held that the job could be done only on an engine lathe. A time-study man, in analyzing this job preparatory to making a time study, believed that the rough and finish boring and the rough turning could be done on a turret lathe. Then, by mounting the bushing on a mandrel, the finish turn could be made accurately on an engine lathe. This was tried successfully, and a 45 per cent reduction in machining time resulted.

An operation done on a bench by hand can sometimes be partly done on a machine to advantage. Riveting is sometimes done on a bench when a saving in time and an improvement in appearance might be effected by upsetting the rivets with a hammer just enough to hold them in place and then by finishing the job on a rivet spinner.

Jigs and Fixtures.—Wherever the quantity warrants, special jigs and fixtures should be used, as they effect a great saving in time and assure more accurate and uniform work. Multiple jigs and fixtures, *i.e.*, those made to hold several pieces, should be applied whenever it would be an advantage to do so. Indexing and rotary fixtures should be used in machining operations wherever possible, as they very often make it possible to reduce the time for performing an operation to the time required to remove and place the part to be machined. Self-centering devices on lathe operations should be used where practicable. Often it will be found to an advantage to secure two fixtures where it is necessary to remove the fixture to reload it. The operator can then load one while the cut is being made on the other.

The time-study man should continually try to effect savings by the elimination of elements of the operation through the application of specially designed fixtures. To give an example of what can be accomplished by the application of special fixtures, a job that was formerly ground on a plane surface grinder was held

in a vise during the operation. It was suggested that a multiple fixture be made so that the job could be done on a Blanchard grinder. Accordingly, a fixture to hold 20 pieces was designed and made. The work was transferred to the Blanchard grinder and a saving of 80 per cent in time was made.

In the operation of "point and face under head" in making machine bolts, an element of the operation was made unnecessary by a somewhat different type of fixture. The bolts, during the machining operations, are held and driven by a socket held in a chuck. Formerly when the bolt was finished, the operator,

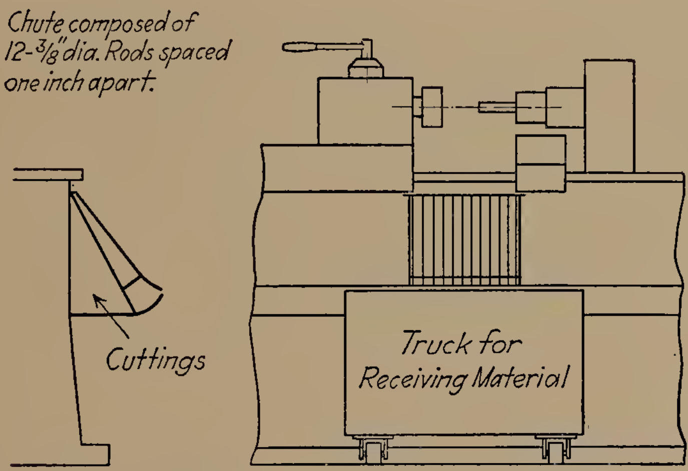


FIG. 2.—Chute for separating bolts and cuttings.

without stopping the machine, knocked it out of the socket, and it fell, together with the cuttings, into the pan of the machine. This made it necessary for the operator to stop work periodically to separate the bolts from the cuttings. A simple chute shown in Fig. 2 was designed and attached to the machine. This chute, a grating of parallel bars, guides the bolts into a box truck and allows only the cuttings to fall through into the pan. The time formerly spent in the separating operation is thus given to machining which, of course, brings about an increase in production at a reduction in cost.

Other Equipment.—When an operation is to be performed on a bench, special attention should be given to the location and arrangement of the bench. The design of the bench is often important. A bench is usually considered to be simply a table of indefinite length, about $3\frac{1}{2}$ feet high and about 3 feet wide. In the majority of cases, this type of bench answers the purpose

very well, but in some special instances, the bench may be designed especially for a certain class of work with a saving of time and effort. For example, where it is necessary to glue flakes of mica together to form a large sheet, the work bench should be tilted on an angle so that the operator may be able to see and reach all parts of the bench easily. In addition, the bench may be made of translucent glass beneath which a light is placed, thus enabling the operator to see easily any bare or thin spots in the mica sheet. This bench not only saves time but also raises the quality of the sheets, for it is almost impossible for a flaw to exist undetected.

Vises particularly suited to the work at hand should be conveniently placed on the work bench. The wrong type of vise for a given job may greatly slow up an operation. For instance, a workman may have some hard straightening to do and only a light vise with which to hold the part. He will have to exert a considerable effort to tighten the vise enough to hold the piece, and even then when he is hammering on or bending the part, it may come loose from the vise causing a loss of time and often bruised knuckles or toes. A heavier, larger vise here will do away with this trouble.

Surface plates should be used on benches where there is any heavy hammering or riveting to do. Having something solid upon which to lay the part will greatly facilitate these and similar operations.

All materials and supplies should be arranged in the most convenient manner possible so that the operator loses no time in needless hunting. Supplies should be placed where wanted within easy reach of the operator. The bench should be clean and orderly.

Handling devices which may aid the performance of the operation should be utilized wherever savings can be effected. Jib cranes are often essential near machines handling large, heavy parts. Gravity-fed chutes, from which supplies may be quickly extracted, a given number at a time, may be utilized to speed up bench operations. Chutes fed by overhead conveyors save a molder much time in filling his flask with sand. The time-study man should constantly seek to use devices which will either improve the quality of the product without increasing the cost or which will decrease the cost without detracting from the quality.

Material Handling and Supplies.—The time-study man must ascertain how the material on which work is to be done is brought to the work station of the operator and how it is removed after the operation has been completed. If the workman has to go for the material himself, he should be allowed time for getting it. Perhaps, in this case, it will be found that so much of the workman's time is spent in getting and removing materials that it will be cheaper to hire a laborer to do this work and thus allow the higher-priced operator to spend more of this time in actual productive work.

The means by which the material is transported from place to place should be considered by the time-study man. Material handling is unproductive labor and should be reduced to a minimum. Many ingenious devices may be made to fit special conditions. Specially designed racks or bins, moved from place to place by lift trucks, may be helpful in handling delicate or highly finished work to keep it from being injured through contact with like parts. Again, it may be found advisable to change the layout of several work stations so that material may be passed from one operator to another by conveyors. In this case, gravity should be used as the conveying power wherever possible, because of the advantage of initial cheapness and low maintenance charges that such systems enjoy.

In putting a storeroom on an incentive basis, the analysis of material handling becomes of paramount importance. Here, outside of a little clerical work, material handling is the only job done. Counting devices, adjustable-partition tote pans, special racks, and the like may be designed to suit each case.

Many jobs require the use of nails, glue, nuts, bolts, lock washers, terminal clips, rivets, and other miscellaneous parts that are commonly called indirect materials or supplies. The amount of time which the operator must spend in getting such materials from the storeroom and in placing them in convenient receptacles around his work station must be considered with the view to later determination of a supply allowance.

Working Conditions.—There should be enough sentiment in business to take the human element into account. It was formerly thought that the workman was not concerned about the conditions under which he labored to earn a livelihood for himself and his dependents as long as he received his wages. The fallacy of this is now generally recognized, and most employers

know that money spent to provide good healthful conditions is an investment which pays dividends.

Conditions, in a general way, may be taken to mean anything which may influence any part of the job, or in other words, anything which may be analyzed may be considered as a condition of the job. For the purpose of this discussion, however, the term "working conditions" will be used to mean any condition which might affect the mind or health of an operator, thereby interfering with the efficient performance of the operation.

Temperature is an important consideration. The most favorable temperature for comfort and efficiency is 65 to 70° F., and this should be maintained the year round as closely as possible. In many places, such as around furnaces or near solder pots, it is nearly impossible to maintain the ideal temperature. Fans or some other kind of forced draft may be used to advantage to keep the air circulating, but in most cases the temperature will be variable. An allowance for such conditions must be made when considering the effort an operator will be able to give throughout the day. The same holds true when the temperature falls below the ideal, as in unheated warehouses in winter and around ammonia refrigerating lines.

Ventilation should be adequate to provide sufficient fresh air at all times. In ordinary work places, such as machine shops or assembly rooms, it is usually easy to insure this through proper arrangement of windows, fans, and ventilators. In many places, however, the matter of proper ventilation offers a serious problem. Acid fumes, dust, and the like must be removed by specially constructed suction devices. Paint shops and dip rooms often abound in unpleasant smells, which, while not actually injurious, are irritating and may cause headaches. An operator cannot be expected to do his best work under such conditions, and if the conditions cannot be corrected, extra allowances must be made.

Daylight is preferable to artificial light and should be utilized wherever possible. Eyestrain due to poor light should always be guarded against. A man cannot turn out accurate work if he cannot read his scales and verniers with ease. He cannot work at his greatest speed if he is not able to see exactly what he is doing.

There should be discipline with a feeling of freedom and cooperation between the supervisors and the workmen, and a

mutual respect and interest for one another's duties, problems, and responsibilities. In general, the entire surroundings and atmosphere should be mutually beneficial, pleasant, and healthful.

Maintenance.—There is a certain amount of maintenance work which must be performed by the operator of a machine. He must oil and clean his machine daily, and he should devote a certain amount of time to a general cleanup of his work station at regular intervals. The time-study man must analyze this work and determine just how much of it is necessary. This he must do so that he may later make a proper allowance for the time expended.

In many other fields, there is some necessary work which must be similarly handled, although it is not maintenance in the strict sense of the word. The time spent in wetting and mixing a supply of molding sand in a foundry when it has dried out over a week-end cannot be charged directly to any one production job, but it is entirely necessary, and due allowance must be made. Where a blacksmith must start his own fire each morning and maintain that fire throughout the day, allowance must be made for time so spent.

CHAPTER VI

STANDARDIZING THE JOB

Analysis and standardization are very closely connected. Every part of a job is first carefully considered, and the pros and cons of each proposed change are duly weighed. Then, when the final decisions are reached, the job is standardized accordingly. Analysis involves thinking of the changes; standardization involves making them.

Generally speaking, standardization is applied to a broader field than is analysis. During analysis, one particular operation is considered. In standardizing, operations as a class are considered and attempts made to standardize those which are similar. Standardization aims not only to make operations alike for any part on a given machine but also to make operations alike for any part on any similar machine anywhere in the plant.

The advantages of standardizing and specializing have been recognized in almost every industry. Few will try to belittle what has been accomplished by standardization in industrial plants where a single product is manufactured. Many, however, believe that this is the only type of plant to which the principles of standardization may be applied. It is true that a single-product plant lends itself more readily to standardization than does the plant manufacturing a variety of products in small quantities. But standardization should not be thus restricted, for there is proportionately as much to be accomplished in the latter case as there is in the former.

Manufacturing Aspects of Standardization.—The importance of standardization cannot be overstated. It brings about reduction of costs and of overhead expense in many ways, both direct and indirect. It changes the job shop which is trying to do everything that comes along and doing nothing well to the specialized shop which first determines what it shall make and then concentrates all of the facilities of the organization on the designing, the manufacturing, and the marketing of the output in the best and most economical way.

In manufacturing, standardization makes possible many things which could not otherwise be done. In the first place, it has cut down the number of designs that go from the engineering department into the shop. This means that it is possible to have longer runs for a given operation with fewer set-ups. The number of drawings and the amount of manufacturing information is reduced. With only a comparatively few drawings, the men using them soon become familiar with them and do not need to spend so much time ascertaining what must be done to finish the operation according to specifications. Often, merely a glance at the drawing title and at the dimensions is enough to tell the operator just what he must do.

When an operation is to be performed on a large quantity of parts it is possible to design special tools, jigs, and fixtures, and thus effect a saving in time which would not be possible were the quantities small and general purpose tools used. Then further standardizing and simplifying of these parts will permit a reduction in the number of tools, jigs, and fixtures themselves.

Where materials are simplified into a few classes and sizes, the stores carried on hand will be greatly reduced. Part of the money tied up in raw materials will be released for more profitable purposes. Not only will the storerooms be smaller and the number of men needed to run them be fewer, but also there will more often be material on hand when it is needed. The delays which were formerly caused by the exhaustion of the store of some special, hard-to-obtain material by an unexpectedly large order will be minimized. This is true also of raw castings and supply material.

The effect of standardization on the worker is very marked. The workman will become familiar with his job more quickly if the job is more nearly the same from day to day. He works with the same materials constantly, and he soon learns how to get the most out of his machine by using the maximum feeds and speeds. When a standard method of procedure has been established and is followed, the operator becomes highly skilled in using this procedure through constant repetition of the same motions. He becomes an expert and, as an expert, will produce more work of a higher quality with less waste, breakage, and lost time than a man working under non-standard conditions.

Supervision is greatly simplified where methods, equipment, and design are standard. One foreman can handle more men and

will not have to bother with details as he would were he constantly studying new jobs and instructing new workers. Not having this to do, he is able to concentrate on the established work of his department and can devote his time to planning better and cheaper methods for doing it. He is freer to study his men so that he may place them on the jobs for which they are best fitted.

Paper routine is reduced to a large extent by standardization. Record files are smaller, cost systems simpler, and timekeeping easier. The non-productive clerical force is smallest where all work is most nearly standard.

The inspection force is also cut down. The inspectors become familiar with the product and know just where to look for defects. This minimizes the possibility of poor work passing unnoticed. The tools of inspection, such as scales, gages, and levels, may, like the tools of production, be fewer in number and better suited to the purpose.

All of these things have the tendency to reduce costs and overhead expense. Non-productive set-ups are minimized, thus allowing the same number of machines to turn out more product or a lesser number of machines to turn out the same product. Lost time, unproductive effort, and idle machinery are greatly reduced. A better quality of product will be turned out at a lower cost of manufacture, and this product will be placed in a more favorable position in the field of competition.

Design.—The point at which to start when considering standardization is at the point where the line to be standardized is born. This is in the engineering department where the designs are first made.

Engineers, like everyone else, wish to be original and want to create something new. This tendency, while laudable in the field of research, must be somewhat suppressed in the field of minor design after the fundamental features to be incorporated in the product have been fully developed. This minor design involves the designing of various sizes, capacities, and the like, for a standard type of product. In designing several of these, the engineer is likely to make minor changes in each size part for no other reason than that he does not want anyone to believe him incapable of working out things for himself. He does not wish to appear to be copying some other engineer's work.

For instance, a cover for a certain class of tanks is to be held down by swivel thumbscrews tightened against lugs. These

covers are used merely to protect the contents of the tank from dirt, dust, and foreign matter of all kinds and do not have to be absolutely tight as they might were they used on tanks under pressure. In designing the cover for 20-, 30-, and 50-gallon tanks, the engineer may call for two, four, and six lugs, respectively. Here, two lugs would be enough to hold the cover in place on any of these tanks. The desire to be different is all that has led the engineer to specify the different numbers. In all probability, he did not realize the expense involved in machining the extra lugs on the cover and in furnishing and attaching the extra swivel thumbscrews to the tank.

Again, a rocker arm shaft may be required for two different types of magnetic contactors. Although the types are different, the purpose of the shaft is the same in either case. Here, if the design be standardized so that the same shaft may be used in either contactor, the same set-ups, tools, and jigs may be used, and the number of shafts carried in the stockroom will be reduced.

Materials.—The physical properties of materials to be used are generally determined by the conditions under which the part is to operate, but often there is a choice to be had among different grades of similar materials. Quite often, the advantage of one grade over another is purely imaginary. In many instances, it is hard to see where the use of one grade in preference to another makes any appreciable difference in the finished part, and the grade selected is often chosen for some minor reason which the advantages of standardization will more than offset. Unless the desirability of standardization be kept in mind during the selection of new materials, there will soon accumulate a large and varied assortment of materials. This leads to waste, since short ends and materials used in making a line which has been discontinued cannot readily be used up. It is necessary to maintain large stocks of raw material, and there is the danger of the supply of some special material becoming exhausted when it is most needed.

The time-study man should not overlook raw materials in his consideration of standardization; rather should he lend every assistance towards reducing the number of kinds and sizes of material used. He may find that a certain part is made from a punching and that another, only slightly different, is made from a casting. He should bring this to the attention of the design engineer and should aid him in determining which form is best

to use as a standard. Wrong applications and unnecessary variations in materials are found quite frequently, and the time-study man should make suggestions to correct such conditions whenever he finds them.

Machine Tools.—In factories where a single product is manufactured, there will be one or more machines used for a single operation. These will have a special set-up, special tools, and equipment made for a single purpose. There will be as many of these set-ups as there are operations. When a time-study man has a condition of this kind to deal with, his work will be comparatively easy; where the work is more of a jobbing nature, it is a different proposition. In the first case, when the time value is established for an operation, the whole group of machines employed on that operation is taken care of, until some change is made and it is only a matter of time before the time-study man has set time values covering every operation performed in manufacturing the product. In the second case, the time-study man must first collect sufficient data to cover every condition that might arise, and then he must repeatedly apply his data to every new job that comes along. The time-study man should, in the latter instance, try to get his conditions standardized as much as possible. He should have as his ideal the shop that is manufacturing a single product even though he knows that he can never reach that goal. He should realize that, just because the product is varied, it is not necessary to have the same number of variations in tools and equipment. At the same time, he should also keep in mind the desirability of special labor-saving conveniences for individual jobs and machines, but that these conveniences should be the same for all like conditions.

There is usually a best way for doing anything, and there is usually a certain make of machine that has advantages over all other makes of similar machines for doing a certain job. This machine may or may not be available, but there will be, among those that are available, one type that will be better than the others. It is not uncommon to see three or four different makes of machines used on the same class of work, and sometimes it is impracticable to control the flow of individual jobs so that they will be performed on the same machine every time they appear in the shop. This condition makes it necessary to determine a time allowance for each machine on which the job may be done, even though this may not be entirely satisfactory.

A good example of this occurred in a machine shop where three radial drill presses were used. On two of these machines, the speed in revolutions per minute ranged from 17 to 240 in seven steps and the feed per revolution from 0.0066 to 0.011 inch. On the other machine, the speed in revolutions per minute ranged from 44 to 474 in 22 steps and the feed per revolution from 0.007 to 0.031 inch. The advantage that the third machine had over the other two is obvious, and since it was impossible to control the flow of work to the individual machines of the group, the difficulties encountered in establishing time values may be appreciated. It was found that the third machine did approximately 35 per cent more work than the other two, and the problem was solved in this case by replacing the first two machines with one of the third type. The two that were taken out were used on other work. Of course, it is not always practicable to do this as the saving effected may not justify the expense.

Another interesting case of non-standard equipment was found in a shop which manufactured electric motor field coils. A group of semiautomatic winding machines was used for winding these coils. The work was studied, and time values were established. One of the operators consistently turned out about 30 per cent more work than any of the others. At first, the reasons for this were not understood. The operators all appeared to be working steadily, and approximately 90 per cent of the time required to wind a coil was machine time and only 10 per cent was handling time. A thorough investigation was made by the time-study man, and it developed that one of the machines had a larger driving pulley than the others. This accounted for the difference. A check was made to determine whether the product of the fast machine was satisfactory and also to ascertain how the machine was standing up. When it was found that everything was all right, it was recommended that all the machines be equipped with larger pulleys. This was done with a resultant increase in output of about 30 per cent and a proportionate reduction in cost.

The time-study man should always be on the lookout for similar conditions and should try to keep the speeds and feeds of like machine tools as nearly standard as practicable. By doing this there will be more production, and the workers will be better satisfied, since none will have any advantage over the others.

Small Tools.—The same thing that is true of machines and all power-driven tools is true of small tools, that is, cutting and hand tools, jigs, and fixtures. The same advantages should be supplied to each operator doing similar work.

It will not be attempted to treat even briefly the subject of cutting tools and of speeds and feeds, as space does not permit. In general, however, tools should be ground in the tool room by men who are experts to insure the proper shapes and angles for the class of work to be performed. One operator should not be permitted to drive screws with a plain screwdriver while another uses an automatic type. Whenever automatic tools can be used to advantage, they should be supplied and their application standardized. Jigs and fixtures should be standardized to eliminate variations in time on the same or similar operations.

Equipment.—All equipment must first be suitable for the work to be done by it. In many cases, it will be found that several different types or makes will perform the work equally well. When new equipment is being purchased, similar equipment used in other parts of the shop should be examined and an effort made to choose the new in conformity to the old. For instance, when considering the installation of a new line shaft, the hangers, bearings, and shaft sizes used in the rest of the shop should be ascertained. If the designer has determined that the new shaft must be at least $3\frac{1}{8}$ inches in diameter and it is found that $3\frac{1}{4}$-inch, but no $3\frac{1}{8}$-inch, shafting is used elsewhere, it will probably be profitable to install a $3\frac{1}{4}$-inch line shaft. Then it will not be necessary to carry spare shafting, bearings, couplings, and pulleys $3\frac{1}{8}$ inches in diameter. In case of breakdown, spare parts may be drawn from the $3\frac{1}{4}$-inch supply already on hand.

In a foundry where patterns may range in area from 1 square inch up to several square feet, standardization of equipment is very important. If a special flask were used for each size of pattern, there would be no end of storage difficulties, delays, and time spent in flask handling, to say nothing of the amount of money that would have to be invested to provide enough of each different size of flask to have on hand when needed; rather should flasks of certain standard sizes be provided to be used with patterns between certain ranges, thus greatly lessening the difficulties mentioned above.

Where electric trucks are used for material handling, it will be profitable to adopt one good make of truck as standard. Then

any driver will be able to operate any truck, and the repair men will be able to do their work more effectively, since they will be thoroughly familiar with the construction of the trucks. Charging equipment and battery units may then be standardized and the stock of repair parts kept may be small.

Relation of Standardization to Time Study.—Just as the workman becomes an expert in his work by constantly doing similar operations on the same materials, so will the time-study man become expert in his work by studying work under standardized conditions. He will know at once whether the best method of procedure is being followed on a new job, because he has previously determined the best method when studying another similar job. He will be better able to judge the effort and the skill of an operator by knowing what effort or what skill this operator or other operators should show when doing this class of work. Any man, when seeing an operation performed for the first time, will compare what is being done to what he could do himself, and if the job requires manual dexterity, he is likely to consider even the poorer operators as skilled. When he has had more experience and has seen really skilled operators work, he is able to judge more exactly what an operator is capable of doing. In this way, his judgment will improve with constant work along similar lines, and he will be able to make more intelligent analyses, determine skill and effort more exactly, and arrive at more consistent time allowances.

The time-study man will be able to play no small part in bringing about and maintaining standard conditions. He is directly responsible for standard methods of procedure. He is able, indirectly, through suggestions which his knowledge of minute details of the work and his analytical point of view enable him to make, to standardize design, equipment, tools, materials. and the like.

CHAPTER VII

TIME-STUDY EQUIPMENT

The success of time-study work depends mostly upon the ability of the time-study man, rather than upon the tools that he uses, for the equipment requirements for making good time studies are simple and few. Yet he must have those few things and know how to use them properly in order to do satisfactory work. The principal items of equipment are:

A time-study watch.
A speed indicator.
Time-study forms.
A pencil.
An observation board.
A slide rule.

The Time-study Watch.—The watch is, of course, the most important item of time-study equipment. Various kinds of watches from the ordinary timepiece to very complex stop watches have been used or advocated by time-study authorities. The ordinary watch may be read in hours, minutes, and seconds, the latter being the shortest units of time that it will indicate. It is useful to record the time of day at the beginning and at the end of a time study, but the ordinary watch is not a practicable instrument for detailed observation, primarily because of the difficulty in reading it and because the second is not commonly used as a unit for the measurement of working time. Authorities, therefore, have generally agreed that some form of stop watch gives more satisfactory results. Three common types of stop watches are:

The split-second stop watch.
The minute-decimal stop watch.
The hour-decimal stop watch.

The Split-second Stop Watch.—The most widely known type of stop watch (see Fig. 3) is the one which is ordinarily used by timekeepers of athletic events, particularly running. The circumference of the dial is graduated into 60 divisions each of

which represents 1 second. Every fifth graduation is numbered to facilitate reading. Each space representing 1 second is in turn divided into fifths which makes it possible to read accurately to fifths of a second. The watch is started, stopped, and the hand returned to zero by pressing the stem. This type of watch is very well adapted to the kind of work for which it was designed, the accurate timing of one particular operation such as a 100-yard dash. During the preparations previous to the starting gun, the hand is held motionless at zero, and the watch is not running. At the sight of the flash from the starter's pistol, the timekeeper presses the stem of the watch, thus setting it in

FIG. 3.—Split-second stop watch.

operation. When the runner touches the tape, the stem of the watch is again pressed stopping the hand instantly and holding it where it is until the watch can be read accurately at leisure. The hand can then be returned to zero by again pressing the stem.

In time-study work, however, one elemental operation follows another immediately, and the end of one is at the same time the beginning of the next. The time required to stop the watch, read it, return the hand to zero, and start it again, although short, is sufficient to introduce appreciable errors. These errors can be eliminated by using the continuous method of reading the watch, but then the closeness of the graduations and the fact that they

are fractional make it next to impossible to read the moving hand and record the readings accurately for short operations, and would require considerable subsequent calculations.

The Minute-decimal Stop Watch.—The minute-decimal watch illustrated in Fig. 4 is more satisfactory than the split-second watch. It is similar in that a complete revolution of the hand consumes 1 minute. The dial is graduated decimally into hundredths rather than sixtieths, which makes it considerably easier to read and reduces the amount of calculation necessary to translate elapsed time into the commonly used units for expressing time values.

FIG. 4.—Minute-decimal stop watch.

The Hour-decimal Stop Watch.—The hour-decimal watch, illustrated in Fig. 5, has a number of distinct advantages over the two kinds just described, and is the type which was used in making all the detailed time studies which will be described or referred to in this book. Chief among its advantages is that it is read directly in hours, the most common unit of time measurement in industry. The length of a working day is expressed in hours; wage rates are expressed as so many cents an hour; payroll calculations are on the basis of hours worked. It is, therefore, advantageous to have time values recorded directly in hours, because of the reduction of the necessary calculations and the

elimination of one source of clerical errors. The dial is divided into 100 spaces each of which represents 0.0001 hour, thus making one revolution of the hand equivalent to 0.01 hour. Having the same number of spaces on the circumference of the dial, this watch is no more difficult to read than the minute-decimal watch; yet because the hand is running at a faster rate of speed, it tends toward more accurate measurement of elapsed times.

The hour-decimal watch is controlled by the slide *A* and the winding stem *B* as indicated in Fig. 5. The slide controls the

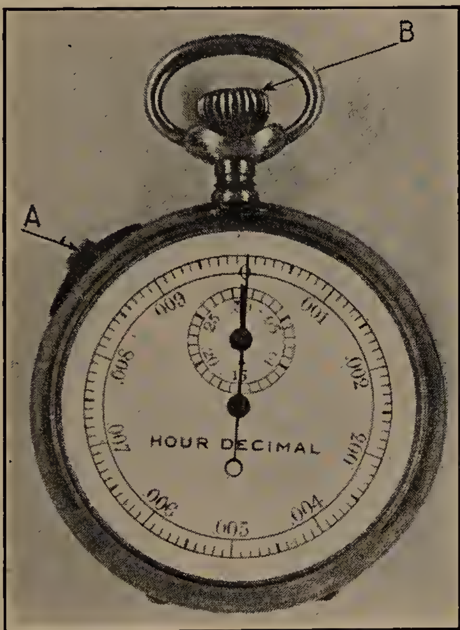


Fig. 5.—Hour-decimal stop watch.

starting and stopping of the watch and makes it possible to stop the hand at any point in a revolution and to start it again from that position. By pressing the stem *B*, the hand is returned to zero, but it starts immediately upon release of the stem, thereby making it unnecessary to press the stem again to start the hand, as in the case of the split-second watch. If it is desired to hold the hand to zero, this may be done either by holding the stem down or by pushing the slide *A* away from the stem. The position of the large hand on the dial indicates accurately to four decimal places time in hours, and the small hand indicates hundredths of an hour directly on its dial and is controlled in synchronism with the large hand by means of the slide and stem.

When using a stop watch, there is a tendency to assume that as long as it will run, it is keeping accurate time, but this is not always true. A man will notice very quickly if his ordinary watch is not keeping accurate time, because he compares it frequently with the many other timepieces he sees. A stop watch, not being essentially an instrument for telling the time of day, may be running too fast or two slow and not be noticed unless it is periodically checked with a timepiece of known accuracy. The ordinary stop watch is not a high-grade mechanism and may require

Seconds	Decimal minutes	Decimal hours	Seconds	Decimal minutes	Decimal hours
1	0.017	0.00028	31	0.517	0.0086
2	0.033	0.00056	32	0.533	0.0089
3	0.050	0.0008	33	0.550	0.0092
4	0.067	0.0011	34	0.567	0.0094
5	0.083	0.0014	35	0.583	0.0097
6	0.100	0.0017	36	0.600	0.0100
7	0.117	0.0019	37	0.617	0.0103
8	0.133	0.0022	38	0.633	0.0106
9	0.150	0.0025	39	0.650	0.0108
10	0.167	0.0028	40	0.667	0.0111
11	0.183	0.0031	41	0.683	0.0114
12	0.200	0.0033	42	0.700	0.0117
13	0.217	0.0036	43	0.717	0.0119
14	0.233	0.0039	44	0.733	0.0122
15	0.250	0.0042	45	0.750	0.0125
16	0.267	0.0044	46	0.767	0.0128
17	0.283	0.0047	47	0.783	0.0131
18	0.300	0.0050	48	0.800	0.0133
19	0.317	0.0053	49	0.817	0.0136
20	0.333	0.0056	50	0.833	0.0139
21	0.350	0.0058	51	0.850	0.0142
22	0.367	0.0061	52	0.867	0.0144
23	0.380	0.0064	53	0.883	0.0147
24	0.400	0.0067	54	0.900	0.0150
25	0.417	0.0069	55	0.917	0.0153
26	0.433	0.0072	56	0.933	0.0156
27	0.450	0.0075	57	0.950	0.0158
28	0.467	0.0078	58	0.967	0.0161
29	0.483	0.0081	59	0.983	0.0164
30	0.500	0.0083	60	1.00	0.0167

Fig. 6.—Conversion table showing equivalents of seconds expressed in decimal minutes and decimal hours.

frequent regulation, especially when it is considered that it does not ordinarily receive as careful treatment as a good watch. When checking the accuracy of a stop watch, the test should not be limited to 1 or 2 minutes but should extend over at least a half hour.

Conversion Tables.—For the sake of clearness and uniformity, all numerical examples given in this book are expressed in decimal hours. If it is desired to convert any time values to either decimal minutes or seconds, it may be done readily by reference to the conversion tables shown in Figs. 6 and 7. Accurate conversions may be made by means of the following formulas:

Decimal minutes	Decimal hours	Decimal minutes	Decimal hours	Decimal minutes	Decimal hours
1	0.0167	8.25	0.138	32	0.533
1.25	0.0210	8.50	0.142	33	0.550
1.50	0.0250	8.75	0.146	34	0.567
1.75	0.0290	9	0.150	35	0.583
2	0.0330	9.25	0.154	36	0.600
2.25	0.0380	9.50	0.158	37	0.617
2.50	0.0420	9.75	0.163	38	0.633
2.75	0.0460	10	0.167	39	0.650
3	0.0500	11	0.183	40	0.667
3.25	0.0540	12	0.200	41	0.683
3.50	0.0580	13	0.217	42	0.700
3.75	0.0630	14	0.233	43	0.717
4	0.0670	15	0.250	44	0.733
4.25	0.0710	16	0.267	45	0.750
4.50	0.0750	17	0.283	46	0.767
4.75	0.0790	18	0.300	47	0.783
5	0.0830	19	0.317	48	0.800
5.25	0.0880	20	0.333	49	0.817
5.50	0.0920	21	0.350	50	0.833
5.75	0.0960	22	0.367	51	0.850
6	0.100	23	0.383	52	0.867
6.25	0.104	24	0.400	53	0.883
6.50	0.108	25	0.417	54	0.900
6.75	0.113	26	0.433	55	0.917
7	0.117	27	0.450	56	0.933
7.25	0.121	28	0.467	57	0.950
7.50	0.125	29	0.483	58	0.967
7.75	0.129	30	0.500	59	0.983
8	0.133	31	0.517	60	1.000

Fig. 7.—Conversion table showing equivalents of minutes expressed in decimal hours.

$$\text{Decimal hours} \times 60 = \text{decimal minutes or } \frac{\text{decimal minutes}}{60} = \text{decimal hours.}$$

$$\text{Decimal hours} \times 360 = \text{seconds or } \frac{\text{seconds}}{360} = \text{decimal hours.}$$

Other Devices.—Numerous mechanical and electrical devices to aid in reading and recording observations have been invented and placed on the market. Where conditions are such that the use of a time-study machine is justified, the comparatively high initial cost will be saved in a short time because of the greater volume of more accurate work that it can do.

The Speed Indicator.—This item of time-study equipment is not required for every time study that is made, but it is very useful when studying machining operations where cutting speeds

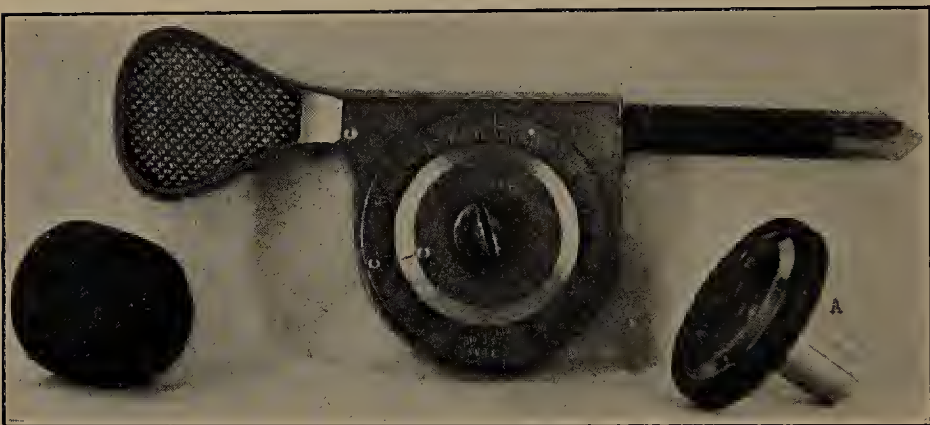


FIG. 8.—Speed indicator.

are an important factor. Even though nearly every modern machine tool has attached to it a table showing spindle, tool, or table speeds for the various gear and belt combinations, experience has shown that these charts should not be relied upon entirely, because the purchaser of the machine tool does not always install it strictly according to the manufacturer's recommendations. Variation in line-shaft speed or in the diameter of the line-shaft pulley will naturally result in actual machine speeds that do not conform to those calculated by the manufacturer of the machine tool. It is, therefore, advisable actually to measure machine speeds when the study is being made.

There are various styles and designs of revolution and speed counters, which will fulfil a time-study man's requirements. The type illustrated with attachments in Fig. 8 has been found

entirely satisfactory for ordinary purposes. For determining spindle or shaft speeds, it may be used without attachments if there is a center hole in the end of the shaft. The reading on the dial shows revolutions for the time the counter was held against the end of the shaft. It is then a simple matter to calculate the revolutions per minute. Attachment *A* is used when it is desired to measure surface speeds. It may be used to determine speed of translation or of rotation merely by holding the small rubber wheel against the moving surface so that the axis of the wheel is in a parallel plane with and perpendicular to the direction of motion. Since the diameter or circumference of the small wheel and the number of revolutions for a measured period of time are known, the speed in feet per minute can readily be calculated.

Time-study Form.—The time-study form is an item of time-study equipment on which almost nothing has been done toward general standardization. Practically every plant and time-study engineer develops and uses a different form, and although no two are exactly alike, there will be found decided similarities in some of the essential features. There are a few fundamental requirements which the time-study form should fulfil, chief among which are:

Convenience for using and filing.

Convenient arrangement of ruling.

Provision for summary of data.

Provision for full and complete identifying information.

The size of the time-study form should be such that it is not too large and cumbersome to handle while making the observations, yet it should not be so small that more than one sheet is required for a short simple study. The regulation 8½- by 11-inch letterhead size has been found to be satisfactory, chiefly on account of the convenience for filing.

The ruling should be so arranged as to permit an economical use of paper and the recording of a maximum number of observations on one sheet. The form should be designed to facilitate the recording of observations in natural sequence. Whether the successive watch readings shall be recorded in horizontal lines or in vertical columns is largely an arbitrary matter, and there is little to choose between the two methods provided the form is of good design otherwise. The design of the form will be influenced to a considerable extent by the method to be employed

in reading the watch. The two principal methods of reading the watch will be discussed in the next chapter, so it will suffice to say here that the continuous method requires practically

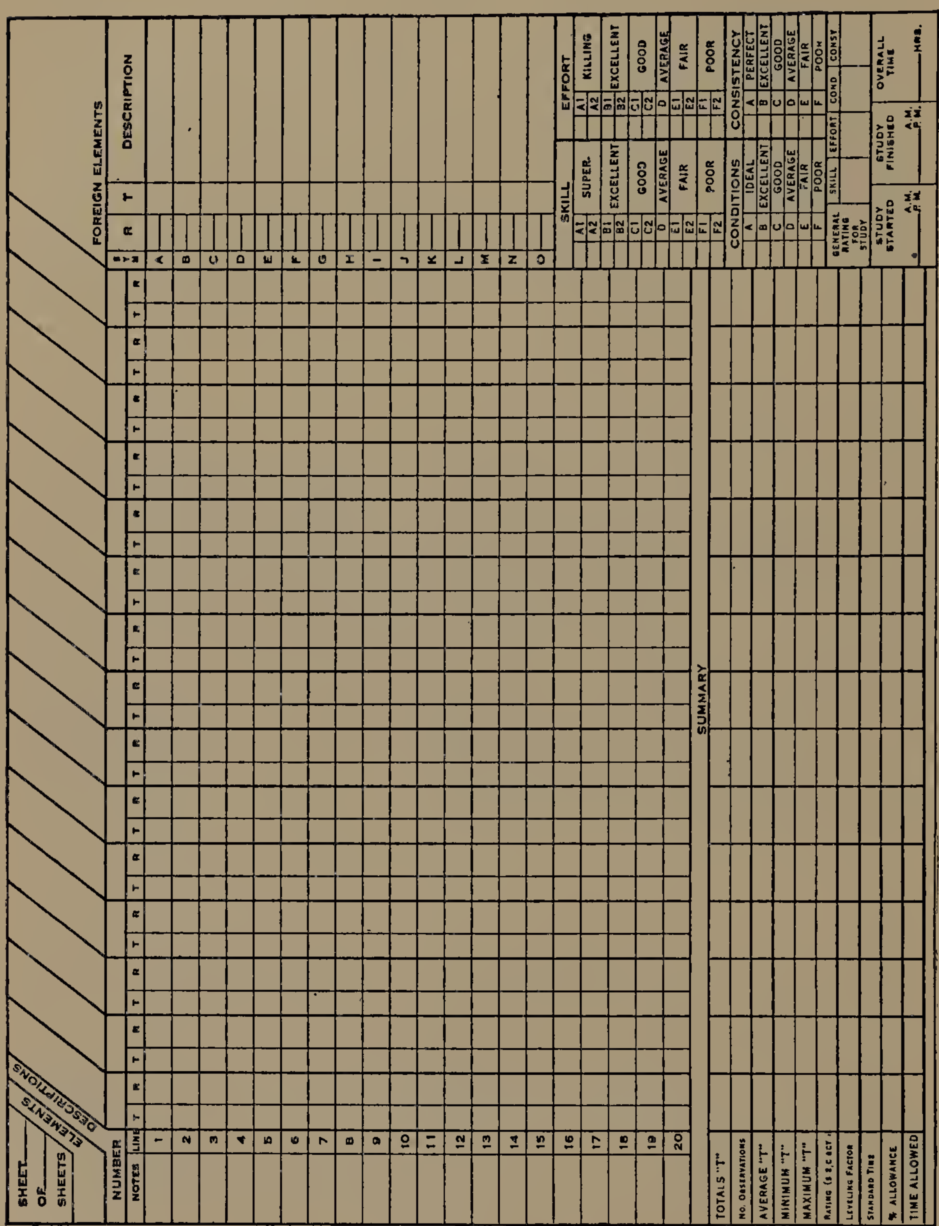


Fig. 9.—Face of time study form.

twice the space for recording observations as is required when using the snap-back method. In the first case, a space must be provided for the continuous watch reading for each detailed element as well as a space for the elapsed time for each element.

In the second case, only the space for elapsed time is required, because the elapsed time is read directly for each element.

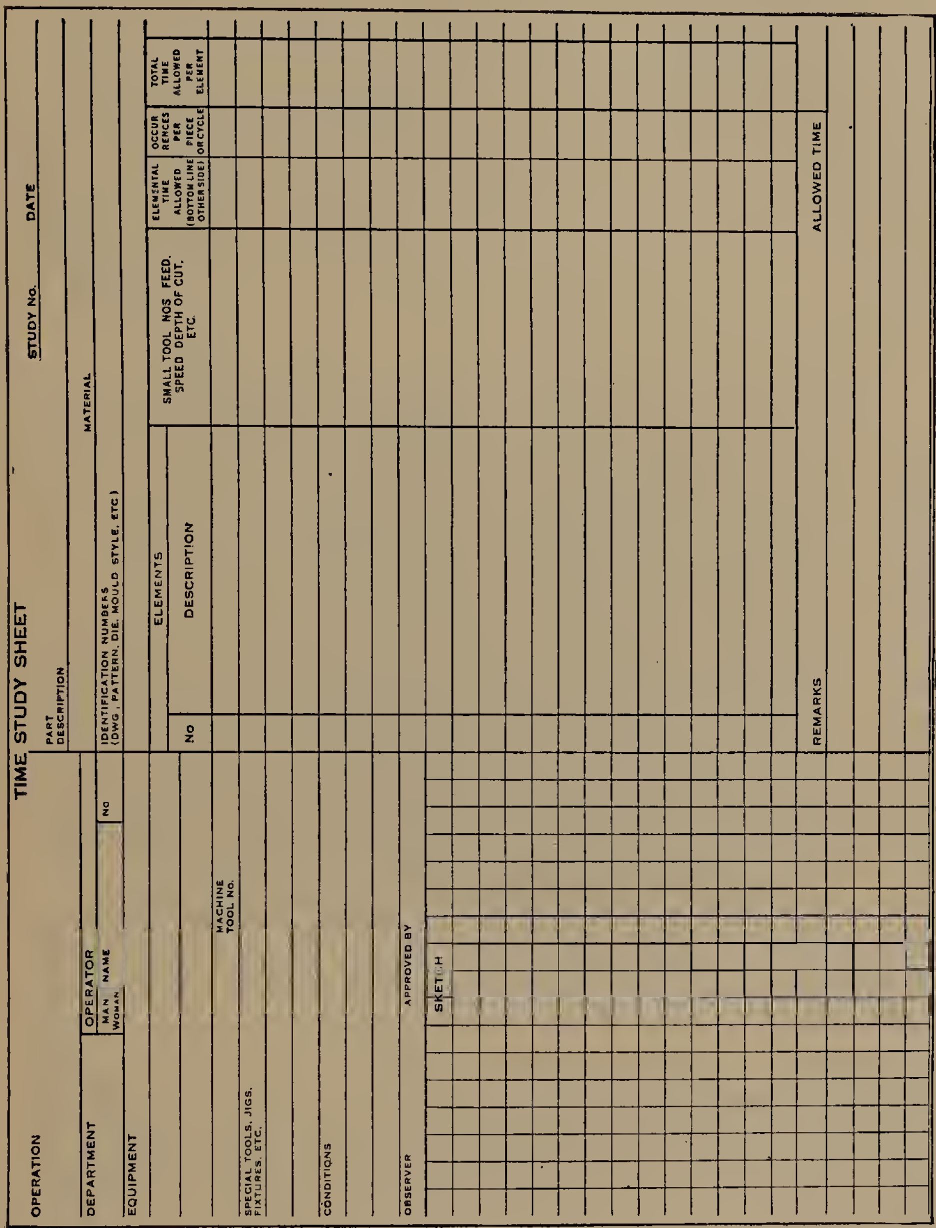


FIG. 10.—Back of time study form.

Provision should be made on the observation sheet for summarizing the data in an orderly form so that the calculation of proper time values will be simplified.

The time-study sheet should provide adequately for the recording of all identifying information and facts pertinent to the job

studied. It should plainly indicate what information is necessary so that there will be no excuse for omitting essential facts and identifying numbers or descriptions. Sketches aid materially in visualizing the job, and a definite space should be allotted on the time-study form for this purpose.

The time-study form which is illustrated in Figs. 9 and 10 is the outgrowth of a number of years of development and is recommended by the authors for general time-study work. It will be seen that this is the horizontal style of form providing for the detailed elements to be listed across the top of the sheet and for the successive observations to be recorded in horizontal lines.

Figure 26 shows how the model time study would appear on a form of the vertical-column type. The same data as shown in Fig. 25 have been reproduced except that the fourteenth observation as shown in Fig. 25 has been omitted from Fig. 26. This causes slight changes in some of the numerical values in the various stages of the calculations but does not affect the ultimate results.

The form illustrated by Figs. 9 and 10 was also designed for the continuous method of reading the watch, although the snap-back method can be used if desired. The oblique spaces along the top of the sheet provide for descriptions of the elements, and the first line immediately below is for numerical symbols which are convenient reference identifications. Each column as marked by the heavier ruling is subdivided into two narrower ones. The one on the right headed *R* is for the watch reading, and the other headed *T* is for the elapsed time. Thus, when making subtractions later, the elapsed-time figure falls conveniently and naturally between the two watch readings which determine it.

The Pencil.—Little need be said regarding this item of a time-study man's equipment except that, for the sake of neatness, the pencil should be kept sharply pointed and should be of sufficient hardness, say 3H or 4H, to prevent smearing or obliteration, because a time study is sometimes subjected to considerable handling and reference. As an aid toward keeping the point of the pencil in good condition, a small piece of emery cloth or sandpaper may be fastened on the observation board. A few strokes over this abrasive when time permits during the study will keep the pencil point well sharpened. The pencil should also carry an eraser.

The Observation Board.—The time-study man is generally obliged to stand up and often to move about while making his observations. When it is remembered further that he must concentrate his attention simultaneously upon the movements of the operator and the hand of his watch while holding his time-study forms and his watch in one hand and busily writing down the watch reading with the other hand, it will be appreciated that some device for holding firmly the watch and the forms will be of considerable assistance. A thin light board similar in design to the one illustrated in Fig. 11 has been found to be quite satis-

FIG. 11.—Time study observation board.

factory for this purpose. A device for holding the watch is attached to the top of the board, and a strong spring clip for holding the time-study sheets is placed in the upper right-hand corner. By standing in the proper position the time-study man can bring directly into his field of vision the three things demanding his attention, namely, the operator, the watch, and the time-study sheet. Since the sheets are held by one corner only, they may be be readily leafed over and allowed to hang over the edge of the board when more than one sheet is required for the study. The photograph in Fig. 12 illustrates the proper method of holding the board.

The Slide Rule.—The slide rule is, of course, not indispensable, but a time-study man will find it a very useful time-saving tool in computing time allowances, adding percentage allowances, and

FIG. 12.—Manner of holding the observation board while taking a time study.

in constructing and applying formulas. Space will not be taken here to describe the principles and applications of the slide rule, but its use is strongly recommended.

CHAPTER VIII

OBSERVATIONS

Broadly speaking, observations include the securing and recording of all data and facts necessary to the computation of the time value, but this chapter will be confined to a discussion of only those observations which are made, and can be made at the time and place of performance. They include breaking the job up into its elements and listing them in their proper sequence, reading the watch and recording the readings, and making a memorandum of the skill and of the effort displayed by the operator.

Position of the Observer.—The time-study man should stand in a position such that the hands of the operator are visible and so that the watch attached to the top of his board will come into this same line of vision. If conditions permit, the time-study man should stand a few feet away and in back of the operator so that he will not interfere with the operator or distract his attention. It may be necessary to move about occasionally for certain kinds of work. He should hold the time-study board firmly with his left hand and arm and in a position that will be comfortable and natural for writing. Figure 13 illustrates the proper position in which the observer should stand with respect to the operator.

The time-study man should stand up while making observations. This creates a favorable psychological effect upon most workers, especially upon those who are not accustomed to working under observation. There is a natural resentment on the part of most operators for a time-study man who settles himself comfortably in a sitting position to watch them work and to make a record of their performance. The confidence and respect of the working force is so difficult to secure at the outset when introducing time-study work that they should never be jeopardized by apparent laziness on the part of the time-study man. Furthermore, it is a recognized fact that a person is more alert when standing than when sitting. Time-study work demands alertness and concentration to a maximum degree, and

this should be sufficient reason for standing while making observations.

Motion Study or Breaking Job into Elements.—All physical activity, regardless of the magnitude of the ultimate accomplishment, consists of a series of comparatively short and, in themselves, simple motions. This is true whether one is considering a laborer unloading coal or a skilled mechanic assembling an

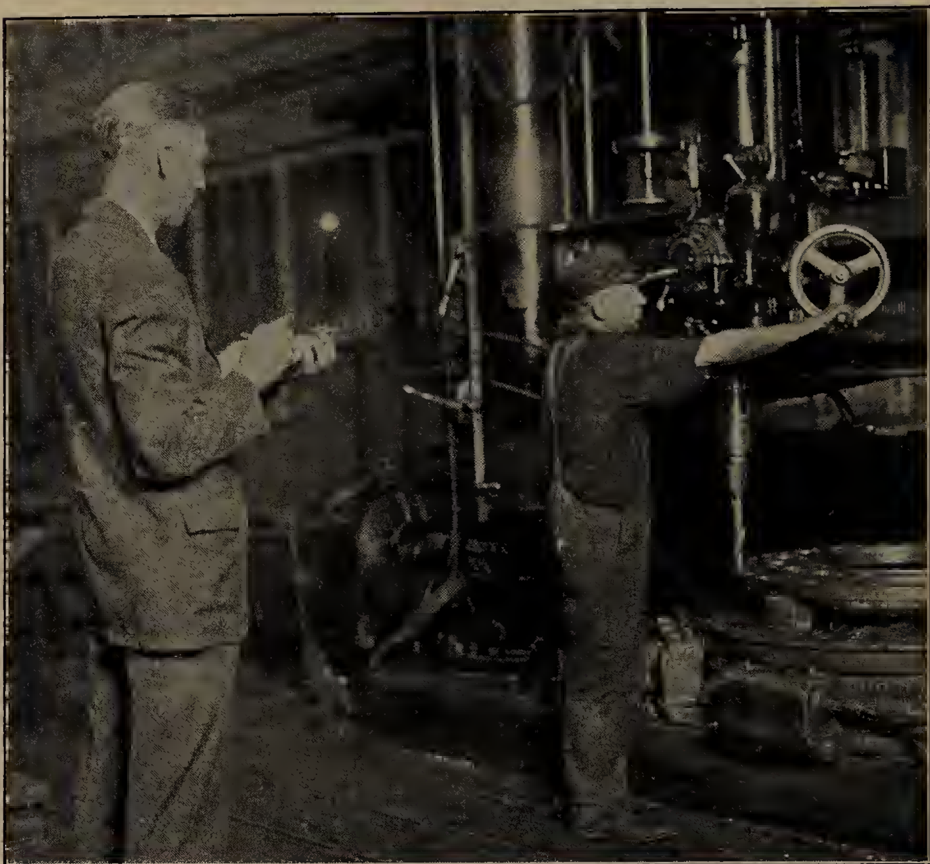


Fig. 13.—Position of the observer while taking time study.

aeroplane motor. Both operations may be subjected to the same close analysis with the result that the first will resolve itself into but two or three elemental motions while the second becomes hundreds or even thousands of distinct and different motions. It is conceivable that considerable variation in the methods of dividing jobs into their elements can exist. No fixed rule can be established practically which will define exactly to what extent jobs should be divided. Different jobs and different classes of work will demand different treatment. Even time-study men

will differ in opinions, especially when the point in question is one which calls for a more or less arbitrary decision. There are, however, a few general principles which should always be kept in mind.

The first and chief one of these principles is that the basic fundamental of time study is the studying of a job by studying its elements, and the shorter these individual elements are the better they lend themselves to close study. A job, therefore, should be divided as minutely as is consistent with accuracy in taking the observations. The advantages of further subdivision are more than offset by the disadvantages of inaccurate readings. For instance, it is humanly impossible to observe and record accurately the watch readings for a dozen successive elements each of which is no longer in duration than 0.0002 hour or consuming a total elapsed time of 0.0024 hour, whereas three or four elements occurring in that same 0.0024 hour would be comparatively simple to handle with accurate results. This does not mean, however, that elements of but 0.0002 hour's duration should always be combined with others to make longer ones. One or even two very short elements, if they fall between comparatively long ones, are not difficult to observe and record, for the readings can be remembered and recorded during the next element of greater length.

Another point which should be considered when dividing a job into its elements is that there are two main classes of elements, constants and variables. A full discussion of these two classes of elements will be presented in a later part of this book under the general subject of formula construction, so it will be sufficient to say here that a constant is an element which should require no more time when it is a part of one job than when it is a part of another job performed under the same working conditions and when the same equipment is used. Conversely, a variable is an element the length of which will be, or may be, different when it occurs in different jobs, as influenced by the characteristics of the individual jobs, such as weight, size, length, and shape. The point to be borne in mind in connection with constants and variables is that they should be kept separated. If it is necessary to combine short elements, the combinations should be limited to constants, if at all possible.

The steps taken in making a complete time study will be illustrated by a series of figures (Figs. 14, 19, 20, 24, 25, and 28)

showing a model time study at various stages of completion. Figure 14 shows how a time study on facing, pointing, turning, and threading a copper stud will appear at the completion of the motion study.

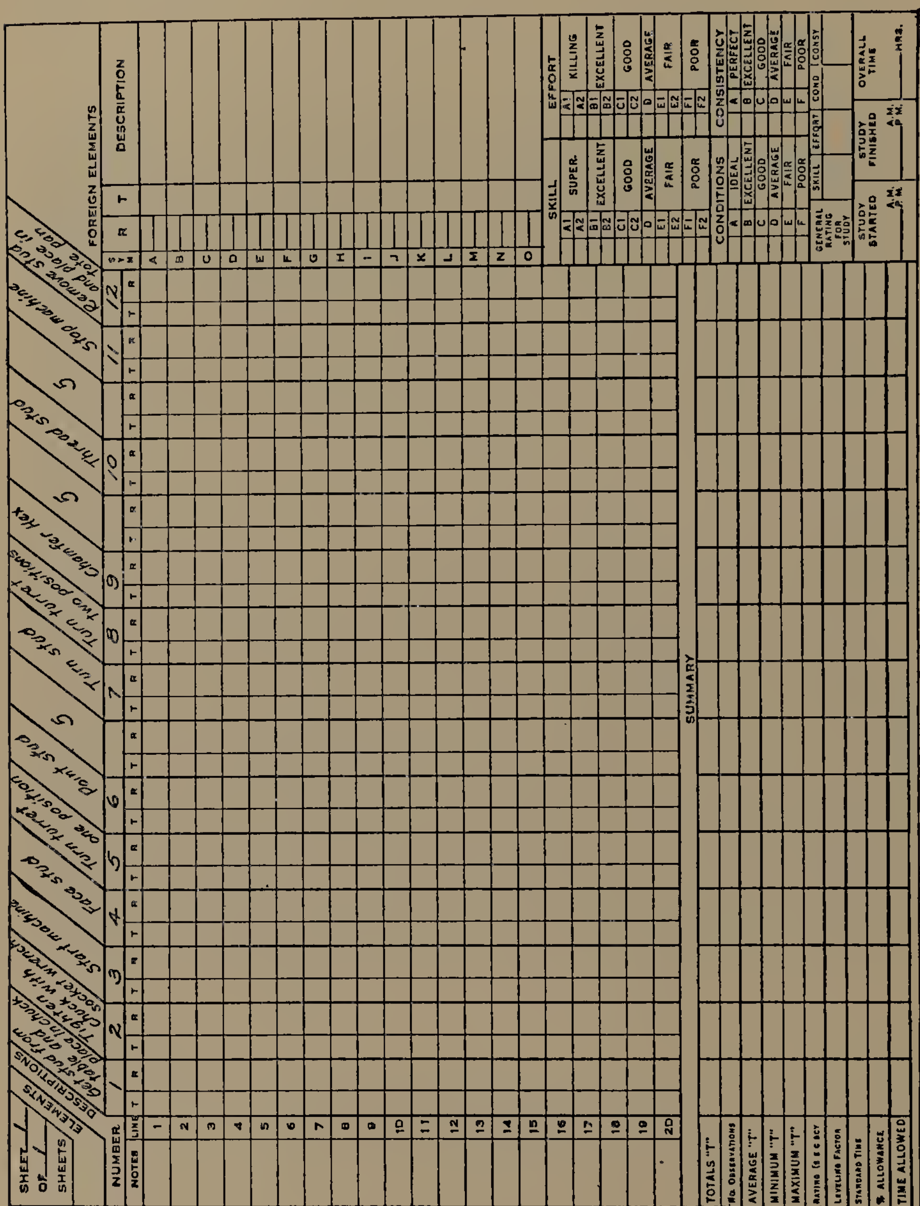


FIG. 14.—Model time study showing motion study completed.

When arranging the sequence of elements on the time-study form, it is desirable to keep the study on one sheet if feasible, on account of the possibility of two or more sheets becoming separated, resulting in the loss of part of the data. Another

advantage is that there are no pages to be turned during the observations.

The time-study form illustrated in Figs. 9 and 10 was described as being of the horizontal-line type, the sequence of elements to

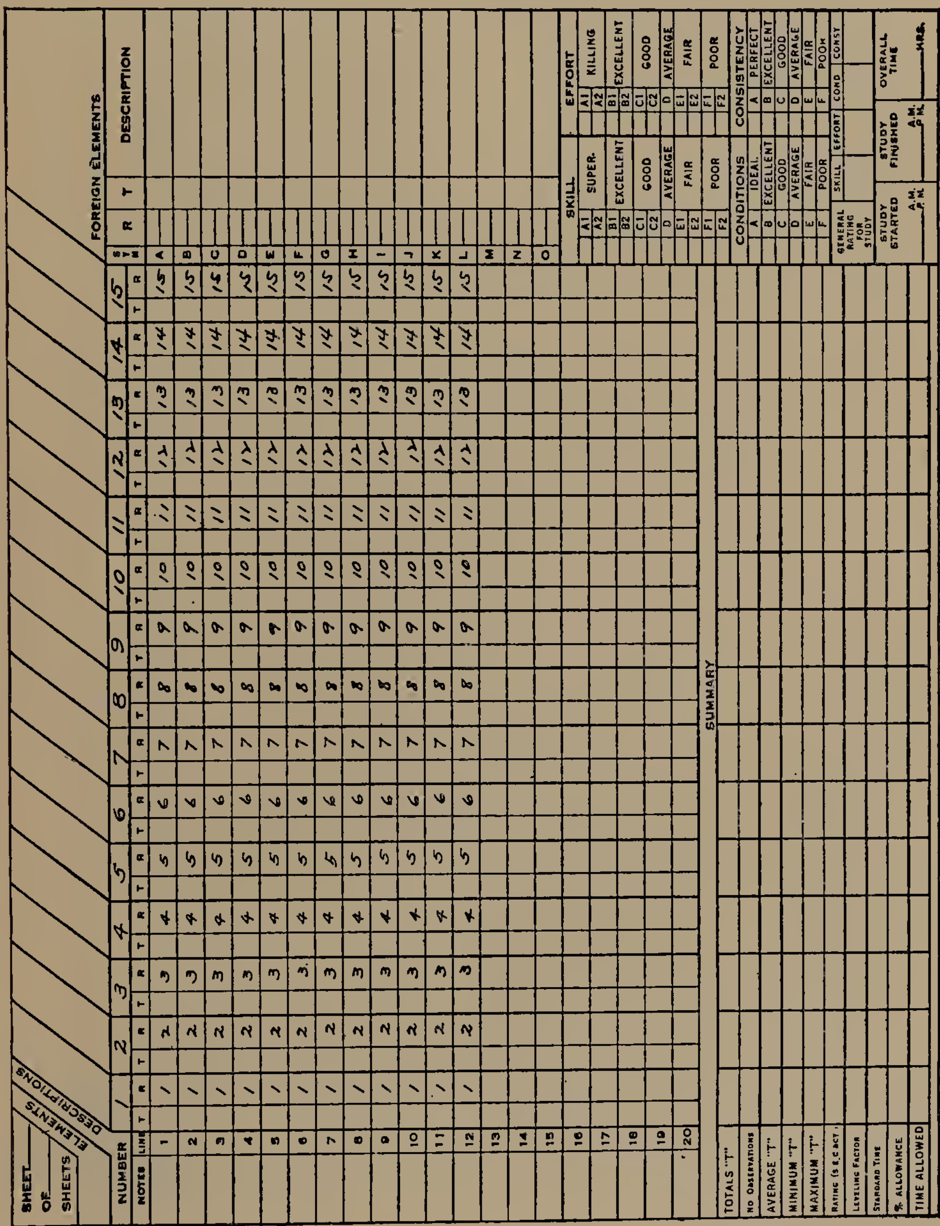


FIG. 15.—See page 66.

be listed along the top of the sheet and successive readings to be recorded in horizontal lines. It does not follow, however, that only one line can be devoted to each piece studied. When the operation consists of a large number of entirely different ele-

ments, there is no alternative but to list them, one to each diagonal space at the top of the sheet, and using as many sheets as are necessary to provide for one complete cycle. Many times, however, one or more elements or series of elements are repeated

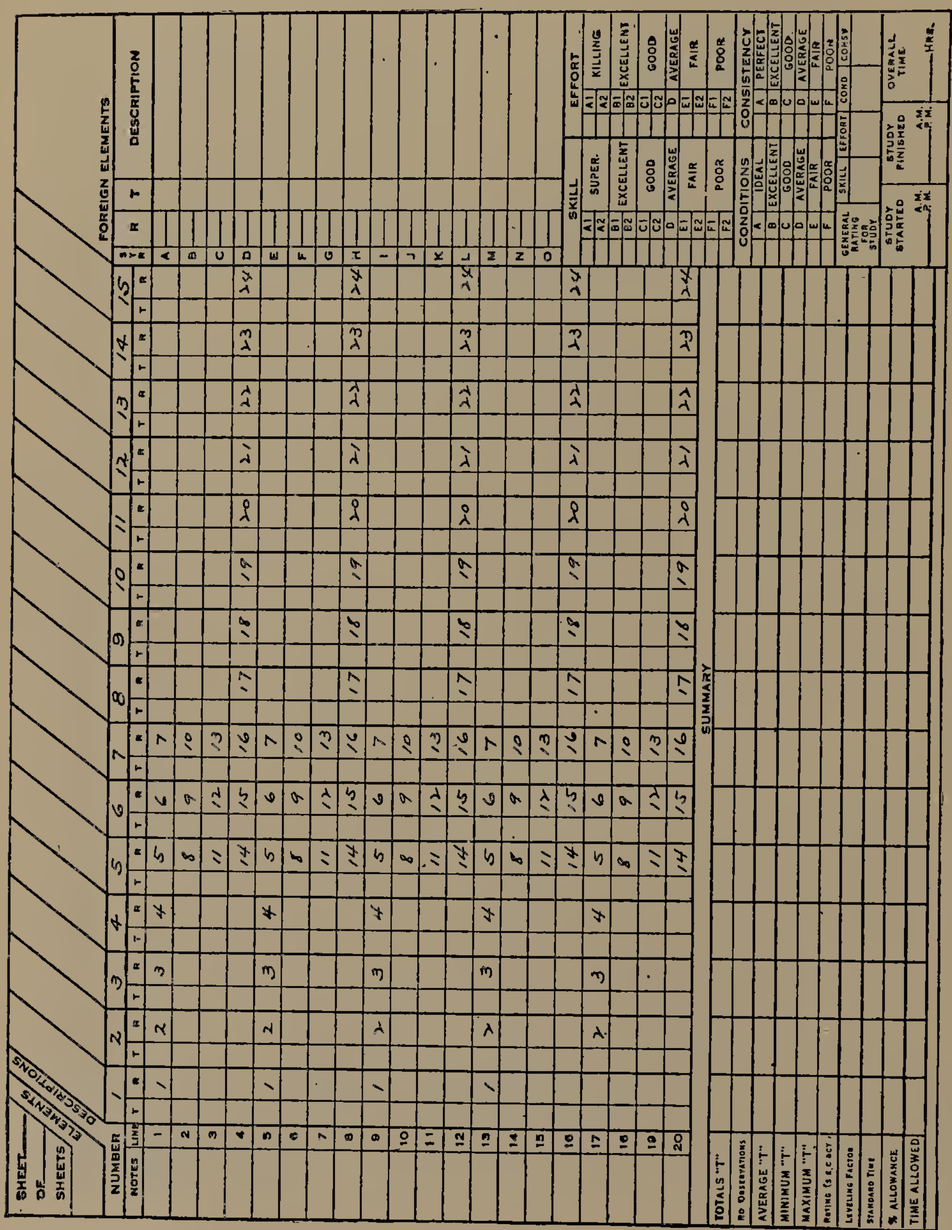


Fig. 16.—See page 67.

a number of times in every cycle or on every piece. It is frequently advantageous, in such cases, to record these particular elements vertically, until the last performance of the repeated

elements. The elements to follow should then be contained horizontally on the same line as the last recorded reading for the repeated element. Figures 15 to 18 inclusive show different typical arrangements of the sequence of elements and the observa-

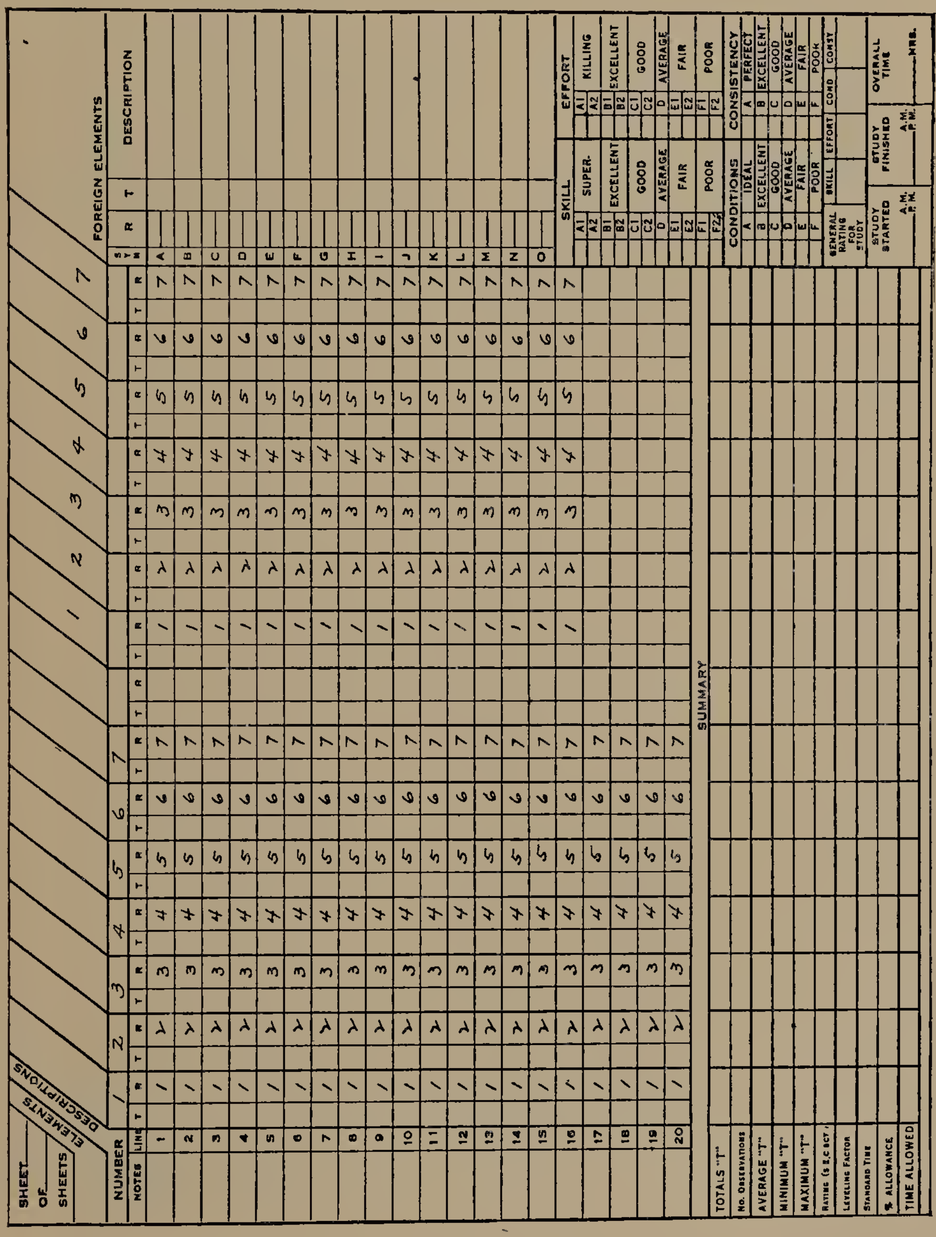


Fig. 17.—See page 67.

tions on the time-study form. These examples do not represent, by any means, all of the different possible arrangements but are merely suggestive of what can be done toward recording the

observations in a condensed form. Figures 15 to 18 inclusive do not show actual watch readings but only the sequence of recording them, the cycle of numbers being repeated as many times as there were pieces observed.

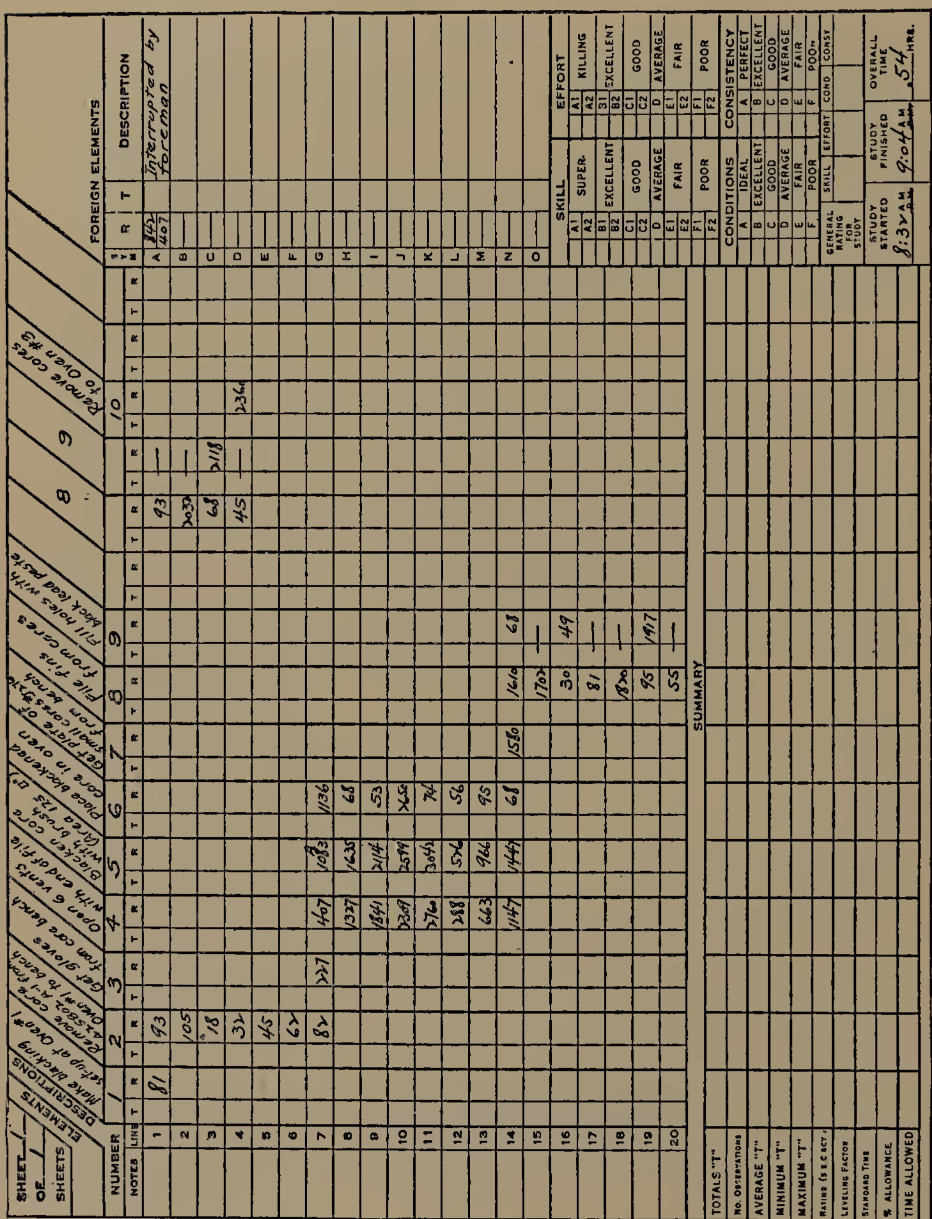


Fig. 18.—Recorded observations of an actual time study showing application of principles illustrated in Figs. 15, 16 and 17.

Figure 15 illustrates the normal arrangement, showing a short operation of 15 elements. Even though some elements may occur more than once on each piece, it is not necessary to record them vertically, because there is ample room for the full number

of elements on each horizontal line. If, however, there had been 24 elements in the cycle, as in the case illustrated in Fig. 16, it would have been impossible to keep the study on one sheet without recording the repeated elements 5, 6, and 7 vertically. Having repeated elements recorded vertically also facilitates making the summary at the bottom of the sheet.

If it is desired to observe more than 20 pieces for a very short operation, an arrangement similar to that shown in Fig. 17 is convenient. The example shows how the observations for an operation of seven elements covering 36 pieces can be confined to one sheet.

Figure 18 shows the recorded observations of an actual study in which the principles described above were followed. This example combines features illustrated in both Figs. 16 and 17. The observations of element 2 which was repeated seven times are recorded vertically as were also the group consisting of elements 4, 5, and 6 which was repeated, in the order given, eight times. After the pair of elements 8 and 9 were repeated seven times, bringing the observations to the last line on the sheet, there were still a number of unused vertical columns, so the observer skipped one column and returned to the top of the sheet in accordance with the principle illustrated in Fig. 17. It will be readily seen that this study which has been kept on one sheet would have required no less than four sheets to have recorded horizontally the 50 observations shown, as there are but 15 vertical columns to a sheet. The method which was used in the example given not only makes the observations much easier and confines the entire study to one sheet but it also greatly simplifies the summary and computations.

A good time-study man will exercise his ingenuity in arranging the sequence of elements to the best advantage and in accordance with the demands of the particular job at hand. He will, with practice, be able to visualize how the time-study sheet will appear when the observations are finally recorded and will be influenced accordingly in listing the elements.

The limited space provided on the form for describing the elements calls for a familiarity with the work and for a nice choice of words on the part of the time-study man. Each element must be clearly defined, which means using words and terms which are exactly descriptive and which will preclude the possibility of ambiguity and confusion with another element which

is only slightly different. The importance of this point might seem to justify revising the form to provide more space, but the form herein recommended has been used satisfactorily by expert time-study men, and the advantages to be gained by revising this particular feature would be more than offset by the disadvantages of less space for other features. A number of examples of poorly defined elements are listed below with better descriptions opposite.

Poor Descriptions	Better Descriptions
Pick up part	Pick up small part from table
Get drill	Get $\frac{3}{16}$-inch drill from tool room
Back off table	Back off table 3 inches
File	Ream two mounting holes with file
Drill hole	Drill hole $\frac{1}{4}$ inch in diameter by $\frac{3}{4}$ inch deep
Get wrench	Get S wrench from drawer
Tape leads	Tape two leads 3 inches
Go to drill press	Walk seven paces to drill press
Turn turret	Turn turret, two positions

Reading the Watch.—Accuracy in reading the watch is developed from practice. A novice will undoubtedly find it difficult to read the watch and record the readings correctly, especially for an operation of many short elements. Unless he has been particularly instructed on the point, he will probably shift his gaze back and forth between watch, operator, and time-study sheet. To look from the watch to the sheet and *vice versa* is not difficult, because both objects are about the same distance from the eye. When looking from the watch to the operator and back again, it will be found more difficult because of the momentary confusion while refocusing the eyes for the difference in distance. This tiresome eyestrain and tendency toward uncertainty can be greatly relieved by avoiding the actual shifting of the gaze between watch and operator; rather should the eyes be kept directed on the watch. The movements of the operator and terminations of the elements should be observed without actually looking away from the watch. If the observer stands in a proper position and holds his watch so that it comes almost in a direct line from his eye to the operator, it is not necessary for him to take his eyes off the face of the watch in order to see every move made by the worker. The termination of elements is also frequently marked by distinctive sounds, such as laying down a tool, the click of a latch, and the change in sound when a

drill breaks through the under side of a metal part or when a cutting tool ceases to cut metal upon arriving at the end of the cut. These can be noted instantly by one who is familiar with the work.

The watch should always be read at the termination of the element. This is generally marked by a sound, as referred to above, or by a reversal of direction or some other decided change in the motions of the operator. Occasionally it is difficult to find a natural division point between two elements, and the time-study man must be unusually careful to take his reading at the same point each time.

Snap-back Method.—One of the two principal ways of reading the watch is called the snap-back method, which means that the hand of the watch is snapped back to zero at the end of each element. Its most important advantage is that the elapsed time for each element is read directly, which facilitates the recording of readings for operations which were performed out of the predetermined sequence and reduces the subsequent clerical work. In using this method, however, there are numerous disadvantages which seemingly outweigh the advantages. There are elements of inaccuracy introduced, such as the time required to snap back the hand and the danger of snapping it back too early or too late.

At the end of an element, the exact position of the hand can be fixed with the eye, but it takes a brief, but nevertheless appreciable, instant for the mind temporarily to record the reading so that it may be permanently recorded on the sheet with a feeling of certainty as to its accuracy. During this brief instant, the hand is moving on and the snapping back cannot then coincide exactly with the recorded reading. Anxious to avoid this slight error, the observer may snap back the hand too soon, before the reading has been fixed in his mind with certainty. Then he is not sure that what he records is absolutely correct.

The snap-back method makes the work of the time-study man more difficult because it gives him more to think about. He must synchronize perfectly three different things at the termination of every element, namely, the observing of the motions of the operator as the exact point which separates each element from the one to follow, the making of a mental note of the position of the hand on the dial of the watch, and the snapping back of the hand. At best, the observations require the utmost alertness and concentration on the part of the time-study man. The use of

the snap-back method, instead of the continuous method, makes still greater demands upon his attention, which will naturally affect the accuracy of his work.

Continuous Method.—As an alternative to the snap-back method there is the method wherein the watch is allowed to run continuously from the beginning of the observations to the end. The position of the hand at the termination of each element is mentally noted and recorded, but this reading does not indicate elapsed time for the element. Elapsed time is secured by subtracting successive readings, which is done after the observations have been completed. When using the continuous method of reading the watch, the observer does not interest himself, for the time being, in elapsed times. His sole object is to record accurately the watch readings for each element, since he knows that elapsed times can be determined later by subtraction. It is a distinct advantage for him not to have continually before him the elapsed times for previous occurrences, as in the snap-back method, for then there is no tendency for him to be influenced to try to keep his readings consistent, but he will record what actually happens whether the results later prove to be consistent or not. This is, of course, what is desired—an accurate and complete record of what happened.

The additional clerical work which this method entails may be held to be a disadvantage, but it will be realized that this part of the work can be delegated to a comparatively low-salaried clerk and the slightly increased cost justified by the greater accuracy made possible at the time of the observations. The fact that the watch readings are recorded continuously facilitates checking back over the study for errors. Every moment of time from the beginning of the study to its end is accounted for. This is of considerable advantage in case the time value, which is finally established, is questioned by the workman or anyone else interested. It is possible to point out how the operator employed his time, even including the extent and nature of the delays and unnecessary work.

Unusual circumstances frequently arise while the observations are being made, and the continuous method is found to be better adapted to handling them than is the snap-back method. On long elements that extend over several revolutions of the hand, it is necessary to read not only the large hand but also the small one. Under the continuous method, the attention can be wholly

centered upon the large hand and its reading accurately fixed in the mind before attempting to read the smaller one, which can be done more leisurely. The snap-back method requires that both hands be read simultaneously with the snapping back, because the small hand as well as the large one goes back to zero when the stem of the watch is pressed. Also, when a foreign element occurs, interrupting a regular element, the snap-back method requires one or two undesirable alternatives. The watch may be stopped and the hand held in its last position until the regular element is resumed, which means that no record is made of the foreign element, or the watch must be snapped back three times during that element, once at the beginning of the interruption, again at the end, and lastly at the end of the regular element.

The continuous method furnishes a ready indication for the time-study man as to whether his stop watch is accurate from a time-keeping standpoint. It is only necessary to compare the final reading with the overall time as determined by his other watch.

Recording Watch Readings.—The hour-decimal watch is read in ten-thousandths of an hour, or to four decimal places. It is not necessary, however, to record all four figures for every element, except when the elements are long enough to extend over one or more complete revolutions of the hand or at the termination of an element during which the hand passed zero. The time for actually writing down the figures is thus reduced to a minimum. The way to record readings can best be illustrated by assuming a series of elements and listing opposite them the full watch readings and these same readings as they would actually be recorded, as shown on the following page.

In only three cases in the foregoing example was it necessary to record more than two figures (elements 6, 9, and 16). During element 6 the hand completed its first full revolution in passing from 0.0098 to 0.0123. As it passed zero, the small hand reached the first graduation on the small dial indicating 0.0100 hour. The reading on the small hand need not be recorded again until another full revolution of the large hand is completed, as it is understood that all intermediate readings are preceded by 0.01 even though it is not shown.

During element 9 the hand passed through zero twice while going from 0.0184 to 0.0313, the elapsed time being 0.0129. Element 16 was the longest of all, extending from 0.0397 to

0.1013. It covered an elapsed time of 0.0616 and was the first case where it was necessary to record four figures.

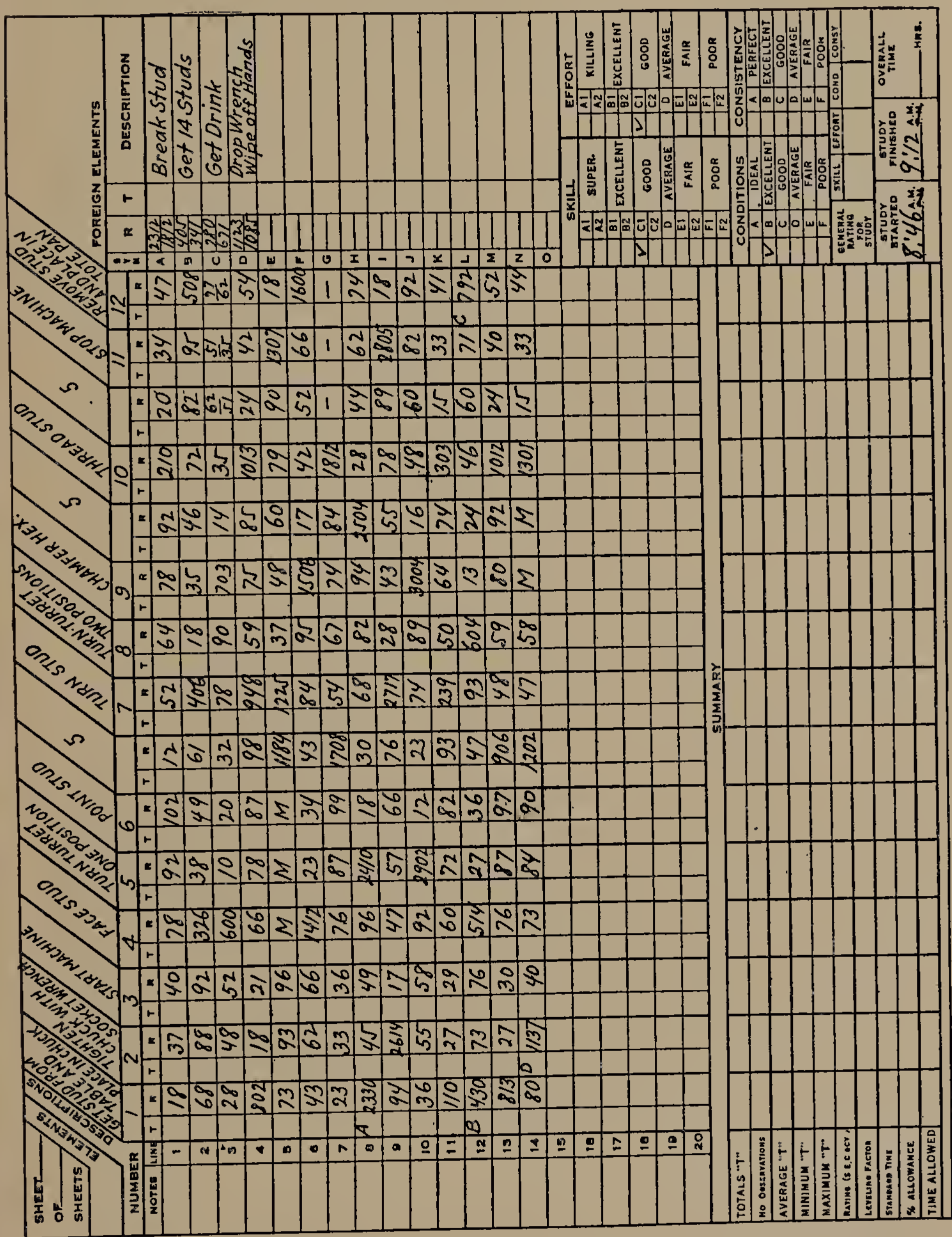
Element	Full reading, decimal hours	Recorded reading
1	0.0012	12
2	0.0020	20
3	0.0056	56
4	0.0071	71
5	0.0098	98
6	0.0123	123
7	0.0162	62
8	0.0184	84
9	0.0313	313
10	0.0321	21
11	0.0330	30
12	0.0342	42
13	0.0361	61
14	0.0382	82
15	0.0397	97
16	0.1013	1013
17	0.1017	17
18	0.1023	23
19	0.1040	40
20	0.1043	43
21	0.1054	54

Variations in Sequence.—After the sequence of elements has been established according to the best arrangement, the time-study man should insist upon this sequence being followed, because any departure from the regular order interferes with the recording of the readings and complicates the study in general. Sometimes, however, variations from the regular sequence are legitimate, and when they occur, the time-study man must be prepared to handle them properly without becoming confused. Variations may be divided into four general classes:

Elements performed out of regular order.
Elements missed by the observer.
Elements omitted by the operator.
Foreign elements.

Elements Performed Out of Order.—Frequently there are combinations of elements in an operation that can be performed equally well in the reverse order from that which has been arbitrarily decided upon, and the operator may thoughtlessly or

intentionally reverse the order. If this is not a chronic fault, it is better to record the variation than to interrupt the operator to call it to his attention. The procedure for handling this situa-



Line	1 Get stud from table and place in chuck	2 Tighten chuck with socket wrench	3 Start machine	4 Face stud	5 Turn turret one position	6 Point stud	5	7 Turn stud	8 Turn turret two positions	9 Chamfer hex.	5	10 Thread stud	5	11 Stop machine	12 Remove stud and place in tote pan
1	18	37	40	78	92	102	12	52	64	78	92	210	20	34	47
2	68	88	92	326	38	49	61	408	18	35	46	72	82	95	508
3	28	48	52	600	10	20	32	78	90	703	14	35	61/51	51/35	27/61
4	902	18	21	66	78	87	98	948	59	75	85	1013	24	42	54
5	73	93	96	M	M	M	1184	1225	37	48	60	79	90	1307	18
6	43	62	66	1412	23	34	43	84	95	1508	17	42	52	66	1600
7	23	33	36	76	87	99	1708	54	67	74	84	1812	—	—	—
8	A 2330	45	49	96	2410	18	30	68	82	94	2504	28	44	62	74
9	94	2614	17	47	57	66	76	2717	28	43	55	78	89	2805	18
10	36	55	58	92	2902	12	23	74	89	3004	16	48	60	82	92
11	110	27	29	60	72	82	93	239	50	64	74	303	15	33	41
12	B 430	73	76	514	27	36	47	93	604	13	24	46	60	71	792 C
13	813	27	30	76	87	97	906	48	59	80	92	1012	24	40	52
14	80 D	1137	40	73	84	90	1202	47	58	M	M	1301	15	33	44

Sym.	R	Foreign elements: Description
A	2312 / 2212	Break Stud
B	405 / 347	Get 14 Studs
C	280 / 671	Get Drink
D	1123 / 1085	Drop Wrench Wipe off Hands

Summary: Totals "T" — No. Observations — Average "T" — Minimum "T" — Maximum "T" — Rating (S E C Ecy) — Leveling Factor — Standard Time — % Allowance — Time Allowed

Skill: C1 Good ✓ — Effort: C1 Good ✓ — Conditions: B Excellent ✓ — Consistency

Study started 8:46 A.M. — Study finished 9:12 A.M. — Overall time ___ Hrs.

FIG. 19.—Model time study showing watch readings completed.

tion is to draw a horizontal line through the middle of the space for the reading of the element which is being done out of order, record the reading at the beginning of the element (the same as the reading at the end of the preceding element) below the line,

and enter the reading at the end of the element above the line. This must be done for each element which is done out of order and for the first operation after the regular sequence is resumed. Element 11, line 3, in Fig. 19, was performed out of order, having followed element 10 instead of the third repetition of element 5, which would have been the regular order. The reading for element 10 was repeated below the line in the space for element 11, and the normal reading for element 11 was placed above the line. This reading which also marks the beginning of element 5 was placed similarly below the line in element 5 space, and so on. The reading for element 12, the first after resuming the regular sequence, also indicates the beginning of element 1 on the next piece, at which point the normal procedure is again followed.

Element Omitted by Operator.—This should not occur often, and when it does happen, it probably means that the element was not necessary on that particular piece. If, however, the element is omitted on a large number of pieces, the indications are that it was not necessary at all and should not have been included as a regular element in the first place. It is taken care of by merely drawing a horizontal line all the way across the column in the space where the reading would have gone, without recording any readings, but going on to the next element as if it had been performed. Element 9, on lines 15, 17, 18, 20, 1, 2, and 4 in Fig. 18 was a case of this kind.

Element Missed by Observer.—The time-study man should not miss or fail to record any watch readings, but sometimes his attention is momentarily distracted from his work or he relaxes his concentration, and before he realizes it, an element is completed, and the time for observing the watch reading has passed.

In a case of this kind, he should not attempt to guess at the reading and record his guess, but he should honestly indicate it as a missed reading. The common symbol for this is an *M* placed in the space where the reading should have gone, as illustrated on line 5 under elements 4, 5, and 6 and in line 14 under elements 9 and 15 in Fig. 19.

Foreign Elements.—It is impossible to anticipate the interruptions and delays which will inevitably occur now and then in the course of a time study. Anything of this kind for which no provision was made at the time the sequence of elements was determined is known as a foreign element. It will be noted that the time-study sheet provides for foreign elements, space having

been set aside at the right-hand side of the sheet for this purpose. Sometimes these foreign elements are necessary to the job, and sometimes they are not. An example of a legitimate case would be when, during the time study, the operator found it necessary to replenish his supply of, and perhaps specially to prepare, some particular material necessary to the job. As in the case of omitted elements, necessary foreign elements should not occur frequently, for when a job is thoroughly analyzed and the sequence of elements determined, very few, if any, of those necessary will have been overlooked. Foreign elements also include such departures from the regular sequence as personal requirements, breaking a tool, a slight injury, and unnecessary work. Whether necessary or not, the irregularity must be recorded, and the method of recording it depends upon the way it occurs, of which there are two possibilities. It can happen while a regular element is in progress, thus postponing the completion of that element, or it can happen at the end of one element and before the beginning of the next.

When the time-study man realizes, at the completion of a regular element, that the operator is not performing the next element in the sequence, he will recognize readily whether or not it is a foreign element. If it is, he will indicate the chronological position by placing a symbol after the reading for the regular element just completed.

It has been found convenient to use as symbols letters of the alphabet placed in the upper part of the space for elapsed time. The foreign elements should be lettered in the order of their occurrence to correspond with the foreign-element symbols printed at the right-hand side of the time-study sheet. The readings at the beginning and at the end of the foreign element will be recorded below and above the horizontal line which divides the space for recording foreign-element readings. The reading below the line will be the same as the reading for the last completed regular element. While the foreign element is in progress, there is generally sufficient time to make a note of what the operator is doing. If the space provided for the description of the foreign element is not adequate, as many additional spaces as are necessary may be used and the symbols for the spaces canceled. The symbol for the next foreign element will be the one following the last canceled symbol. In Fig. 19, foreign elements *B* and *C*, which were performed between regular ele-

ments, are recorded in this manner. Foreign element *B* was performed between regular element 11 on the eleventh piece and regular element 1 on the twelfth piece as indicated by the *B* recorded in the first column on line 12. Foreign element *C* was performed between regular elements 10 and 11 on the twelfth piece as indicated by the *C* in the last column on line 12.

When the foreign element occurs during a regular element, the point at which it occurs is indicated in the same way as described above by placing a reference symbol after the reading for the last completed element to correspond with the next available foreign-element symbol. The same procedure is followed as was just described, except that the reading below the line will not be the same as the reading for the last completed regular element but will be taken at the point where the regular element was interrupted. The reading at the end of the foreign element will be recorded above the line. The regular element which was interrupted is again resumed, and the reading at its termination is recorded in its proper space. In Fig. 19 on line 14 will be found an example of a foreign element occurring during a regular element. The operator completed element 1 and started on element 2, then interrupted himself, before completing element 2, to perform foreign element *D*, which he completed at 0.1123 as shown at the right-hand side of sheet before resuming element 2, which was finally completed at 0.1137 as recorded in the proper place.

Number of Observations.—The number of pieces to be studied is a matter which cannot be definitely fixed and which must be left largely to the judgment of the observer. This number will be influenced by the length of time required to do one piece and by the number of repetitive elements in each cycle. For instance, an operation of 100 or more elements of which a large percentage are repetitive need not be observed as many times as one of fewer non-repetitive elements. The time-study man should aim to make his study long enough to be representative of normal conditions. The greater the number of observations he has on each element, the more intelligently and accurately can he detect inconsistencies and determine the normal performance time. Beyond a certain point, however, the law of diminishing returns begins to operate, and the advantages do not increase in the same proportion as the time and effort expended in securing additional

readings. Generally speaking, 15 or 20 observations are sufficient on operations of several minutes' duration.

Rating Skill and Effort.—The time-study man should note his rating of the skill and effort of the operator in the space provided on the front of the sheet. He should do this before leaving the scene of the work, while the performance of the operator is still fresh in his mind. At this point, the judgment of the time-study man must be at its best, for the calculations to determine standard time will be based upon these ratings. Once these human factors are determined, almost all of the remainder of the work is mathematical. Although these decisions call for keen judgment on the part of the time-study man, it need not be unguided judgment. Two later chapters are devoted to the discussion of skill and effort, and they describe fully the characteristics which determine the different ratings. A careful study of these descriptions will enable the time-study man accurately to classify the skill and effort of the operator.

Summary of Procedure.—For the benefit of the reader and especially of the student reader, there is presented below a brief summary of the different steps in making observations listed, in the order in which they should be considered.

1. Arrange and prepare time-study equipment.
2. Stand in a proper position with respect to the operator.
3. Divide the job into its elements and arrange them advantageously on the sheet:
   a. Make elements as short as possible without interfering with accurate observations.
   b. Describe elements exactly.
   c. Assign numbers to the elements in the order of their first occurrence as 1, 2, 3, 4, etc. If an element is repeated after its first occurrence use the same number that was first used.
4. At the beginning of the first element to be included in the study, start the hour-decimal watch and read the time of day on the ordinary watch.
5. Record the time of day in the space Study Started in the lower right-hand corner of the sheet.
6. Record the hour-decimal watch readings:
   a. At the completion of element 1, record the watch reading on the first line in column 1 under the letter *R*, the reading at the end of the element 2 in column 2 under *R*, and so on.
   b. Record only the necessary significant figures.
   c. Allow the watch to run continuously.
   d. At the completion of the first piece, allow the watch to run and return to column 1, following the same procedure for the second piece as for the first.

e. Record variations of sequence when the occasion arises and in accordance with the methods previously described in this chapter.

7. Study a sufficient number of pieces to insure a set of data which is representative of the work.

8. At the completion of the last element to be included in the study, record the time of day as indicated on the ordinary watch in the space Study Finished in the lower right-hand corner of the sheet.

9. Make a note of effort and skill on the front of the sheet by checking the term that applies.

10. Sign and date the time study.

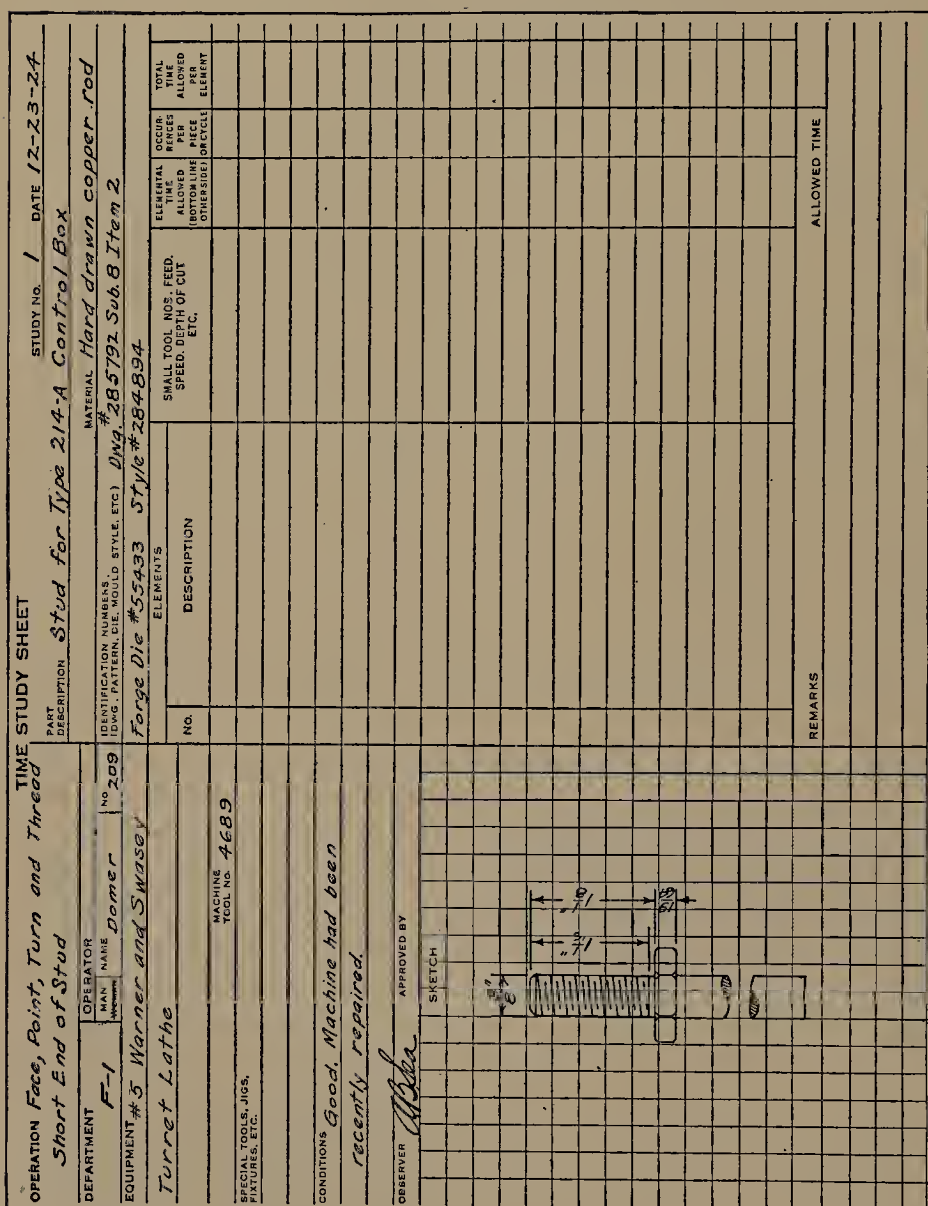
CHAPTER IX

INFORMATION

The application of a good time study is by no means limited to the particular job of which it is a record. Although it is justifiable, in most cases, to make a time study solely for the purpose of establishing a time value on that particular job, it may be found later that the time study is of even greater value for reference purposes or for formula construction. If a number of time studies covering a certain class of work have been made, it is often possible to establish the time value on a new job wholly by means of reference to these time studies. Parts of the new job will be found to be repetitions of parts of other jobs previously studied. The time values for certain of these elements can be taken from one study and those for other elements from another study. When time values have been found for all the elements of the new job, the sum may be used as the time value for the job. When a sufficient number of time studies on the same class of work have been made, a formula may be constructed which places all such valuable reference data at the disposal of the time-study man in the condensed form of charts, curves, tables, and algebraic expressions. Part II of this book is devoted to a full treatment of formulas, but it will not be amiss to say here that the value of a time study for reference or formula purposes depends almost wholly upon the accuracy and completeness of the information which identifies and describes the job. A large number of detail time values are, in themselves, of little or no value unless the job to which they apply and the conditions under which the work was done are definitely known. This is possible only when the time-study man has been extremely careful to record all available, necessary, and relevant information, at the time or immediately after the study was made. He should not regard his study as completed until this has been done.

After the observations have been made accurately and carefully, nothing should be done that will detract from the reference value of the time study, nor should anything be neglected that

might add to its future value. Time-study information is well chosen and complete if it fully identifies all the features of a job, such as the machine, the operation, the operator, the part, the material, and the tools used, so that the job and conditions


TIME STUDY SHEET

OPERATION Face, Point, Turn and Thread Short End of Stud

STUDY NO. 1 DATE 12-23-24

PART DESCRIPTION Stud for Type 214-A Control Box

DEPARTMENT F-1

OPERATOR MAN NAME Domer NO 209

MATERIAL Hard drawn copper rod

EQUIPMENT #3 Warner and Swasey Turret Lathe

IDENTIFICATION NUMBERS (DWG., PATTERN, DIE, MOULD STYLE, ETC.) Dwg. #285791 Sub. 8 Item 2 Forge Die #55433 Style #284894

MACHINE TOOL NO. 4689

SPECIAL TOOLS, JIGS, FIXTURES, ETC.

CONDITIONS Good. Machine had been recently repaired.

OBSERVER

APPROVED BY

SKETCH

ELEMENTS

NO.	DESCRIPTION	SMALL TOOL NOS. FEED. SPEED. DEPTH OF CUT ETC.	ELEMENTAL TIME ALLOWED (BOTTOM LINE OTHER SIDE)	OCCURRENCES PER PIECE OR CYCLE	TOTAL TIME ALLOWED PER ELEMENT

REMARKS

ALLOWED TIME

FIG. 20.—Model time study showing information recorded at time of observation.

surrounding and influencing it can be visualized and mentally reconstructed by someone other than the man who made the time study. Figure 20 shows the information recorded on the model time study at the time of observation.

Operation.—The name of the operation should be short and descriptive. It should be common shop usage and not a duplication of the name of any other operation on the same piece or part. Frequently one word will suffice, such as "turn," "bore," "layout," "assemble," "file," "mold," "saw," and "press." Sometimes, however, it is desirable to use a qualifying word as in "rough turn" or "finish turn," when the general term applies equally well to two or more operations on the same piece. Sometimes several general terms are necessary, as "turn, bore, and face" for a turret-lathe or boring-mill operation which is completed during one set-up. Some plants use the system of identifying operations by numbers, in which case, of course, the operation number should be recorded.

Location and Operator.—The information should show specifically where and by whom the operation was performed. Spaces are provided for the department and for the operator. A record should be made of the name and the check number of the operator and whether a man or a woman. This latter point sometimes affects the matter of allowances.

Part.—The part or piece of apparatus upon which the work is being done should be exactly described and identified. It is not sufficient merely to name the part, as "cover," "shaft," "bearing," or "housing," but in addition, there must be given a description of the apparatus for which the part is being made, as "cover for No. 3 gear box," "crankshaft for Type *RS*-7 engine," or "rear-wheel bearing for 1000-pound truck." The name of the part should always correspond with the name which appears in the bill of material on the assembly drawing or on other manufacturing data. In all well-organized plants, parts are identified by number, as "drawing number," "pattern number," "specification number," "style number," or "mold number." All such numbers are, of course, most important, and as many of them as are available should always be noted. Nothing is more definite as the means of identification than a number, and it will be noted that the time-study form provides adequately for them.

A sketch of the part should always be drawn in the space provided. It is not necessary that it be drawn to scale or that it be accurately proportioned like an engineering drawing. A free-hand sketch is quite sufficient, but it should be drawn in ink and important dimensions should be shown. The light cross-section

lines will aid in making the different parts of the sketch proportional. The copper stud on which the machining time study given as a model was made is shown by the sketch on the back of the time-study form as illustrated by Fig. 20.

Material.—The material being worked upon should be carefully described, considering such points as kind, weight, grade, shape, dimensions, number, and hardness. Some kinds of material are identified in one way and other kinds in other ways. For example, there are different kinds of steel, as cast steel, cold-rolled steel, and tool steel. Steel rails are graded according to weight and composition, as for example, "90-pound manganese-steel rails," which means that they weigh 90 pounds to the yard and are made of manganese steel. Steel is also furnished in different shapes, as sheets, bars, and tubing, sheets being graded according to gage or thickness and bars according to diameters or other sectional dimensions, as "12-gage C.R.S. sheets," and "3-inch axle steel." Wire is identified according to gage number, as "No. 14 tempered-steel wire."

It is not so essential that the material be as definitely specified on pure assembly work as it is on machining or processing work where the material greatly affects the time for doing certain elements. On the ordinary assembly operations, it makes little, if any, difference in the time required whether brass or steel hardware is used, but if it is a machining operation involving the cutting of the material, it is of considerable importance to know whether the material is brass or steel, because brass can be cut at a much higher speed than can steel. The most efficient cutting speeds, feeds, and depths of cut for different kinds of material may be fairly definitely established so that it will be comparatively easy to check up this point to determine whether maximum efficiency is being secured in this respect. Figure 21 shows in tabular form appropriate milling cutting feeds and speeds for some of the common metals. If the condition of the material is abnormal in any respect, this fact should be noted. Castings are sometimes hard or scaly or have excess finishing allowances. Notation should always be made of any substitution for the material ordinarily used on the job being studied.

Equipment.—The equipment employed on the work should be concisely but fully described. When describing the machine tool, for instance, the time-study man should specify the trade name, size, capacity, class, and type, as for example, "36-inch

F-1 Milling Machines—Feed and Speed Chart
Feed in Inches per Minute

For Brass: Cutting speed of 200 feet per minute

Width of cut, inches	Depth of cut, inches					
	1/16	1/8	3/16	1/4	5/16	3/8
Up to 2	14.4	11.2	9.6	8.0	7.0	6.4
Over 2 to 3	13.5	10.5	9.0	7.5	6.6	6.0
Over 3 to 4	12.6	9.8	8.4	7.0	6.1	5.6
Over 4 to 5	12.0	9.1	7.8	6.5	5.7	5.2
Over 5 to 6	11.0	8.4	7.2	6.0	5.3	4.8
Over 6 to 7	9.9	7.7	6.6	5.5	4.8	4.4
Over 7 to 8	9.0	7.0	6.0	5.0	4.4	4.0

For Cast Iron: Cutting speed of 65 to 75 feet per minute
For Copper: Cutting speed of 200 feet per minute

Width of cut, inches	Depth of cut, inches					
	1/16	1/8	3/16	1/4	5/16	3/8
Up to 2	8.0	7.0	6.5	5.3	5.1	3.4
Over 2 to 3	7.5	6.6	6.0	4.8	4.8	3.2
Over 3 to 4	7.0	6.2	5.6	4.5	4.5	3.0
Over 4 to 5	6.5	5.7	5.2	4.2	4.2	2.6
Over 5 to 6	6.0	5.3	4.8	3.6	3.6	2.4
Over 6 to 7	5.5	4.8	4.4	3.3	3.3	2.2
Over 7 to 8	5.0	4.4	4.0	3.0	3.0	2.0

For Steel: Cutting speed 65 to 75 feet per minute

Width of cut, inches	Depth of cut, inches					
	1/16	1/8	3/16	1/4	5/16	3/8
Up to 2	5.3	4.7	4.0	3.2	2.1	1.6
Over 2 to 3	5.0	4.5	3.8	3.0	1.9	1.5
Over 3 to 4	4.6	4.2	3.5	2.8	1.8	1.4
Over 4 to 5	4.3	3.9	3.3	2.6	1.7	1.3
Over 5 to 6	4.0	3.6	3.0	2.4	1.6	1.2
Over 6 to 7	3.6	3.3	2.7	2.2	1.4	1.1
Over 7 to 8	3.3	3.0	2.5	2.0	1.3	1.0

When using cross-feed of machine No. 20030, use 62½ per cent of tabular feed.
When using cross-feed of machine No. 9845 use 54 per cent of tabular feed.
Note: The width of cut used is the sum of all surfaces machined, as shown in Figs. 1, 2, and 3.

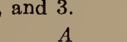


Fig. 1.

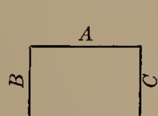


Fig. 2.

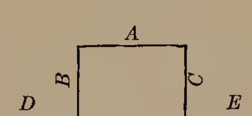


Fig. 3.

Fig. 21.—Speed and feed chart for milling machines.

Bullard vertical boring mill," "24-inch Pratt and Whitney turret lathe," or "No. 3 Cincinnati milling machine." If the plant in which the time-study man is employed assigns identification numbers to its machine tools, this number should, of course, be recorded. It is essential that every detail be given regarding the auxiliary tools used such as cutting tools, arbors, jigs, fixtures, and templates. If they are identified by numbers, these numbers should be given as well as descriptions and sizes. Note should be made of how tools are supplied to the workman, whether he is obliged to go to the tool room for them, or whether they are brought to him. The set-up of the machine tool should be described. This can often be done best by means of a sketch

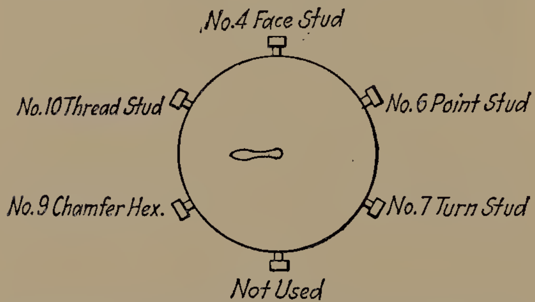


Fig. 22.—Sketch showing the position of tools on the turret as used for performing the operations on which the model time study was made.

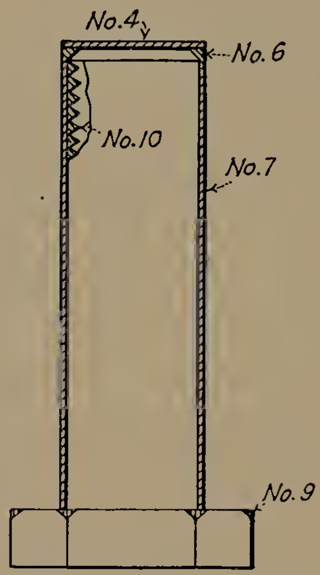


Fig. 23.—Sketch showing the nature of each cut taken on stud on which the model time study was made.

which shows the placing of the tools, methods of holding fixtures to machines, and the like. Figure 22 illustrates how sketches were used to help describe the turret-lathe operation on which the model time study was taken. The arrangement of the tools in the turret is clearly shown, and the elements for which each tool was used are noted. Such a sketch used in conjunction with a sketch of the part as in Fig. 23 aids greatly in visualizing the job, and tells the story more clearly than is possible with words. The sizes and descriptions of all hand tools, such as mallets, pliers, wrenches, and files, should be included in the information recorded on the time-study sheet.

Conditions.—It is important that a record be made of the working conditions existing at the time of the study. If condi-

tions are normal, this fact should be noted, and any abnormal conditions should, of course, be described. The time-study man should note particularly such things as heat, light, and ventilation. This subject has been discussed thoroughly in Chap. V, Analyzing the Job, and the various things that should be considered when recording conditions are enumerated there.

CHAPTER X

SKILL

It will often be observed that, when two men are working on the same job, although they appear to be applying themselves to the work with the same degree of effort, one man produces more than the other. This is due to a difference in the skill or the ability which the two men have developed in doing the operation.

The reasons for this difference are several. Sometimes it is because one man is better suited by nature for the work in respect to stature, physical strength, mental ability, and the like. Since employment departments have been trying more systematically to place a new man on the job for which he is best suited, misfits are becoming more infrequent. If two men are suited in every way for the job which they are doing, the next greatest factor influencing skill is the length of time they have been doing the job. The longer a man has been doing a certain class of work, the more familiar he will become with the details of that work. Constant repetition will enable him to develop a high degree of skill, just as constant practice enables a runner to improve his form and stride and thus lower his time for running a given distance. Other factors which affect skill and which are less easy to detect are the mental state of the operator, health, freedom from worry, and the like.

It is hard to specify degrees of skill exactly, for they are purely relative and are affected by many influencing factors. It is possible, however, to subdivide skill into six general classes, poor, fair, average, good, excellent, and superskill, and to set forth the general characteristics exhibited by an operator that will determine the class to which he belongs.

Poor.—An operator whose skill would be considered poor is usually one to whom the work is new or one who is unfitted by nature for the work he is doing. In the case of the new man who has not had any previous experience on the work, this lack of knowledge is outstanding. It may be that he is engaged on a machine and his lack of experience makes it necessary for him to

stop to think what is to be his next move. After he has decided what it is, he moves with an uncertainty that is quite pronounced. Should he make an error, it will confuse him and may lead him to make more and greater errors. He plainly lacks all the confidence which he will later gain by experience.

Where the skill of an operator is considered to be poor after he has had sufficient time to learn the job, it will generally be found that he is a misfit—the so-called square peg in the round hole. He knows what to do but does not seem to be able to do it with ease. His movements are clumsy and awkward. His mind and his hands do not seem to coordinate, and before he makes a move, he has to stop to consider whether or not it is right. He continually makes reference to specifications or samples and does not seem to acquire the confidence which he should gain by experience. This man, with all of his seeming care and consideration, turns out an inferior quality of work, makes many mistakes, and spoils more work than those more skilled. Time values should rarely be set from the performance of an operator of poor skill. The time-study man should recommend that more suitable work be found for him, for experience has shown that every person is fitted by nature for some kind of work. This should be done in fairness to the employee as well as to the employer.

Fair.—The man who may be considered to possess fair skill may be a misfit who has been doing the job for so long that he has been able to overcome some of his natural handicaps and has risen from the poor class. This case is uncommon, however, for if a man is a misfit, he usually will become dissatisfied with his job and will quit before he has been at the work long enough to develop fair skill.

More often, the man is a comparatively new man but one who has been doing the work long enough to follow the proper sequence of operations without an undue number of blunders. He is still somewhat clumsy and uncertain in his motions, but he seems to have a definite idea of what he is doing. He has become familiar with his place of work so that his attention is not easily distracted, and he is familiar with the location of machine control levers, supply bins, and the like, so that he does not waste time in hunting.

This man has sufficient knowledge of the work to enable him to plan ahead to a certain extent. He does not hesitate much

between operations to think out what he must do next. At the same time, he lacks full self-confidence, because he is still not entirely familiar with the work.

On work which requires a high degree of manual dexterity, this man will find it necessary to spend time repairing mistakes that his lack of skill has caused. A molder who is only fairly skilled will have to devote more time to patching his mold than the skilled man, because he fails to ram his sand properly, or because he is clumsy in drawing his pattern and breaks some of the weak sections of the mold.

The fairly skilled man will be better able to read drawings than the man of poor skill. He has become more familiar with the nomenclature used by the plant engineers, and he knows better where to look for finish marks, dimensions, and other guiding information.

Average.—The man who possesses average skill is the one who is most discussed and the one to whom all others are compared. He is the man who has been on the job long enough to be considered proficient in the work, although he has not been at it long enough to gain that proficiency which comes only of long practice.

He performs the work with reasonable accuracy, and he has confidence in himself. He feels that he has passed the learning stage and is now in position to be considered a full-fledged artisan on his line of work. He follows a set procedure regularly and will make few mistakes, if any. Experience has taught him the advantage of planning ahead, and he makes his mind and his hands work together. He understands his tools and equipment, and he is well able to handle them properly. He has lost that clumsiness and uncertainty of movement due to inexperience.

This man not only reads drawings proficiently and does the work according to specifications, but he is also able to think out things for himself. Because of his familiarity with the work, he will not need to refer continually to his information but will know that when a certain step of the operation is performed, another definite step must follow.

The man of average skill will turn out work which is satisfactory in every respect. He will appear a little slow in his motions but otherwise will give a satisfactory performance.

Good.—The man whose skill may be considered as good is noticeably better than the ordinary run of men found doing the

same class of work. He seems more intelligent and possesses reasoning ability to a marked degree. He will produce more and better work than the average man, with seemingly less effort.

When the man of good skill is first given a new job, he perhaps may not be able to plan the best way of doing it entirely alone. He will, however, respond readily to suggestions, and when he is once started in the right direction, he will be able to continue without constant supervision and instruction. If he does run into difficulties, he will be wise enough to ask for assistance rather than try to blunder on alone.

This man is fairly quick in his motions and is sure of himself. He turns out good work and may be counted on always to do it in less than the allowed time unless he has bad material or trouble with his machine or tools. He displays a good knowledge of all tools, equipment, and materials required in the performance of his job and uses them to good advantage. He understands drawings well and can be depended on to make his work correct to specifications. He is capable of giving good advice to his fellow workers and is able to show short cuts to less skilled men.

Excellent.—An operator whose skill may be considered as excellent is distinguished by precision and certainty of action, speed and smoothness of performance, and self-confidence. At the beginning of the operation, this man visualizes each step from the first to the last. His skill is evident from the very start. He knows what he wants and where to find it. The tools he selects for each element of the operation are the best and the most efficient available, and his set-up is such that it will permit the systematic performance of the elements in their proper sequence. This sequence is never varied. Wherever it is possible to combine operations, the man of excellent skill does it, and often both of his hands are performing different operations which would be done separately by the less skilled man. This operator has a good memory and does not find it necessary to refer to specifications after he has laid the job out mentally. He is definite and certain and does not make mistakes. He understands machines and tools pertaining to his work and uses every available advantage. He makes labor-saving tools and devices. His mind and his hands seem to coordinate automatically. He seems to work without effort and is thorough and accurate. He produces a good quantity and quality, far above the less skilled.

This operator has proved himself fitted for the work that he is doing and has gained the knowledge and confidence which is to be expected from one who has had long experience on the same class of work. He is an agreeable type to study, but the time-study man must not fail to take his skill into account. Otherwise, he might discourage the skilled man from using his ability for the advantage of his employer, for he is right in expecting to benefit from his superiority over the less skilled workman. It is not satisfactory to establish time values that only the excellent in skill can meet or better slightly, for then the average operator would fail to meet the time, and he too would be dissatisfied. If the time value is set so that the average man will meet it and the skilled man materially better it, both will be satisfied. This is a desirable condition, for these classes include the great majority of the workers.

Superskill.—The superskilled operator is not common in industry. Superskill comes from long years at the same line of work. The very fact that methods and equipment change frequently as new and better means are devised prevents men from becoming highly skilled in most lines of work. In the few cases where the nature of the work is unvarying year after year, men who may be considered as highly skilled will be found.

The superskilled operator has all the characteristics of the operator of excellent skill developed to as near perfection as it is possible for a human being to attain. He knows the job so thoroughly that his motions are steady and as quick as those of a machine. He does not have to think about the work but performs the task like an automaton. His hands seem to fly to the proper places without conscious effort on his part. His motions are so smooth and rapid that they are difficult to follow. One operation blends so smoothly into the next that even an experienced time-study man will have to watch very closely to determine the proper point at which to take his watch readings.

This man knows and uses all the best methods and short cuts in doing the job. Very often, he has taken part in the development of these methods and is justly proud of the fact. He stands head and shoulders above the other operators. From the standpoint of the psychological effect on the other workers who may not understand the principle of leveling, it is perhaps best not to time study the superskilled man. The others may feel that the

time value arrived at from this study will be so low that they cannot hope to meet it.

Summary.—In order that the salient characteristics which attend each class of skill may be set forth clearly, it will be well to present them in outline form.

Poor Skill:

1. New man or misfit.
2. Unfamiliar with the work.
3. Uncertain of proper sequence of operations.
4. Hesitates between operations.
5. Makes many errors.
6. Movements clumsy and awkward.
7. Does not coordinate mind and hands.
8. Lacks self-confidence.
9. Cannot read drawings well.
10. Unable to think for himself.

Fair Skill:

1. Misfit on job for a long time.
2. Comparatively new man.
3. Follows proper sequence of operations without much hesitating.
4. Somewhat clumsy and uncertain but knows what he is doing.
5. Fairly familiar with equipment and surroundings.
6. Plans ahead to some extent.
7. Lacks full self-confidence.
8. Loses time due to own blunders.
9. Can read drawings fairly well.
10. Gets same output with less effort than poor man.

Average Skill:

1. Works with reasonable accuracy.
2. Has self-confidence.
3. Is proficient at the work.
4. Follows a set procedure regularly.
5. Understands his tools and equipment.
6. Plans ahead.
7. Coordinates hands and mind.
8. Reads drawings well.
9. A little slow in motions.
10. Turns out satisfactory work.

Good Skill:

1. Noticeably better than ordinary run of men.
2. Markedly intelligent.
3. Possesses good reasoning ability.
4. Responds readily to suggestions.
5. Needs little supervision.
6. Uses machine or tools to good advantage.

7. Fairly quick in motions.
8. Works correctly to specifications.
9. Can instruct others less skilled.
10. Possesses originality.

Excellent Skill:

1. Precision of action.
2. Shows speed and smoothness in performance.
3. Thoroughly familiar with work.
4. Makes no mistakes.
5. Works accurately with little measuring or checking.
6. Operates his machine or tools to best advantage.
7. Can think out best methods for doing work.
8. Makes speed without sacrificing quality.
9. Has full self-confidence.
10. Designs labor-saving tools.

Superskill:

1. The operator of excellent skill perfected.
2. Has been at the work for years.
3. Naturally suited to the work.
4. Works like a machine.
5. Motions so quick and smooth that they are hard to follow.
6. Does not seem to have to think about what he is doing.
7. Knows and uses all best methods and short cuts.
8. Conspicuously the best worker of all.

Conclusion.—If time-study men do not have a guide for their judgment of skill such as has been given in the preceding paragraphs, often no two of them will agree upon the degree of skill being exhibited by an operator. This is merely because each has different mental standards by which he judges skill. With the characteristics as given above firmly in mind, two time-study men should form the same opinion of the ability of an operator. This will tend towards consistency in establishing time values.

CHAPTER XI

EFFORT

Skill is not the only factor that determines how much a man will produce. Two men working with the same degree of skill will accomplish different amounts of work, because one will exert a greater effort in doing the job than the other.

The amount of effort which an operator will put into his work while being studied depends largely upon his attitude toward time study and the time-study man. If he feels that the purpose of the time study is to get more work out of him for the same or less pay, it is only natural that he should assume an antagonistic attitude and do everything in his power to hinder the work of the time-study man. If, on the other hand, the time-study man is a good salesman and can show the man that the true purpose of time study is to establish fair time values under which increased earnings with increased effort are possible, and also that an honest effort on the part of the operator will help the time-study man to determine such time values, then the operator will be glad to cooperate and assist the time-study man to the best of his ability. Some of the other factors which influence effort are health, physical condition at the moment, interest in the work, working conditions, mental condition, and distracting elements.

As in the case of skill, it is hard to specify degrees of effort exactly. Again, however, effort may be subdivided into six different classes, poor, fair, average, good, excellent, and killing, and the characteristics of each determined.

Poor.—A poor effort may be given by an operator possessing any of the six degrees of skill. A poor effort may be malicious or may be caused by lack of interest or may be, so the operator thinks, given as a matter of self-protection. A poor effort should be easily detected by a time-study man, and many of the following points will be noticed when a man giving such an effort is studied.

Many trips for tools will be made when one trip should be sufficient. These trips may be made to the tool room, the

operator's own cupboard, or work bench, or he may be continually borrowing equipment from fellow workmen. The same will be true of materials and other accessories, for instead of analyzing the job and getting everything required in the fewest possible trips, the operator purposely makes a trip for each separate item. This not only requires the extra time to make the extra trips, but it extends the time for doing the other work, because by continually stopping and starting, the operator does not give himself a chance to get into the swing of the work.

Not satisfied with the time lost by unnecessarily running to and fro, he finds it necessary to stop work an unusual number of times to blow his nose, get a drink, or do some other such personal thing. He will interest himself in other things which are apparently out of the ordinary. He will play the part of a good fellow and give advice and demonstrate to fellow workmen where it is not needed. Sometimes he pretends to be ignorant of things that he should know and has known for a long while and asks questions and seeks advice unnecessarily. Unusual trouble may develop with his tools or the materials, and he will try to engage the time-study man in conversation. He tells him what he is up against and how he can neither get the proper tools nor his machine repaired. He also says that the material is not what it used to be and that conditions are not right; and he compares his work with what other men are doing elsewhere. He may try to get the time-study man interested in subjects foreign to the work and may try to get sympathy by talking about his family affairs.

Then again, he wants to impress on the time-study man how important is the operation he is performing and how strict accuracy is absolutely necessary, overlooking the fact that the time-study man has familiarized himself with the requirements and the purpose of the operation. His set-up usually does not permit smooth systematic performance, and he makes many false and unnecessary motions. He does not perform the elements in the same sequence and often starts the same element several times. He makes many mistakes and finds it hard to do anything right the first time but is continually cutting and trying. He will finish the work to a degree of accuracy that is not necessary and which will not be maintained after the time-study man has left, and to obtain this accuracy, he will continually gage and measure his work. He will use wrong tools, such as a smooth file when he should use a rough one or a light hammer when a

heavy one is more suitable. He may use carbon-steel tools when high-speed steel tools could be used to better advantage, or he may try to use tools that are improperly ground. He resents any suggestions for improvement and intimates that they have been tried before unsuccessfully.

The operator gives one the impression that he is lazy and indolent. It may be that he is naturally lazy or it may be that worry, dissipation, poor food, or loss of sleep may have affected him. This man sometimes shows open resentment to the time-study man and time-study methods and tries to spread discontent among the other workmen.

It is possible that this attitude on the part of a workman is justified, but it is rarely the case. More often a man having this attitude is narrow, selfish, and dishonest. In fairness to the great mass of working people, however, it is recognized that this attitude is very much the exception after the workmen have had an opportunity to taste of the fairness of time-study methods.

Fair.—A man exerting a fair effort will be somewhat more reasonable in his attitude towards his work, but he will exhibit a number of the same tendencies which the man giving a poor effort shows. He takes little interest in his work and seems to regard it as a necessary evil. He makes no suggestions himself as to how the operation may be improved in respect to methods, quality of output, or saving in time, and he receives grudgingly any suggestions that the time-study man may make. After some little persuasion, he may half-heartedly try to make some of the suggested changes, but he evinces throughout a lack of cooperation.

He is inclined to be too accurate in his work and will, unless watched, turn out a better job than the inspection standards require. He constantly grinds his tools, after he has once found them, to a point near perfection, at the same time explaining how the importance of the job makes this necessary.

Some of the man's seeming lassitude may be due to poor health, late hours, or some mental dissatisfaction or worry. When a man who ordinarily gives a good effort changes and gives only a fair effort, the time-study man should, in a friendly way, try to ascertain just what is the reason. Often he will find that domestic troubles, financial worries, or something of the sort are keeping the man's mind from his work and are thus slowing him up. Perhaps the time-study man may even be able to help him out of

his difficulties by a little unbiased council and so win his lasting good will.

The man giving a fair effort makes fewer unnecessary motions although there are still some present. He tries to go about his work in some systematic way, and he gives one the impression that he is really trying to do a fair amount of work. It is readily apparent that he is not doing his best, but at the same time, he does not resort to the extreme time killing practiced by the man giving a poor effort.

Some of the man's lost time may be due to nervousness because of the presence of the time-study man. This should not be hard to detect, and when the time-study man finds this to be the case, he can help obviate it by a sympathetic friendly attitude when talking to the man and by remaining unobstrusively in the background during the time study.

Generally, the man gives but a fair effort only because he doubts the fairness of the time-study man, or because he does not understand the principles of time study. The time-study man will in time overcome the doubts in the first case by being absolutely fair in all his dealings with the men in the shop. They will soon realize that he is not trying to get more work from them or to lower their wages but that he is only trying to do his work as best he can and play fair with both the workmen and his employer. In the second case, a man often thinks that he will get a time value in accordance with the total time he takes to do the job less any time which the time-study man may have felt was spent unnecessarily. For this reason, he tries to extend the time. He takes as much time as possible feeling that this is the only way he can get a time value which he will be able to better later. A thorough explanation of the principles of leveling should give the man a better understanding on this point and make him more willing to give a better effort thereafter.

On the whole, the man, although slow, puts some energy into his work, and it will be possible to get a usable time study from him.

Average.—The average effort falls on the border line between the fair and the good effort. It is the effort to which all others are compared, and yet it is perhaps the hardest to define specifically. It is a little better than the fair effort and a little poorer than the good.

The operator exerting the average effort works steadily and with fairly good system. He will not deny that he is not doing

his best, but he feels justified in holding back because he somewhat doubts the fairness of time study or of the time-study man. These doubts may often be overcome in the manner discussed above.

Lost motions are reduced, and the man appears to take some interest in the work. In short, he shows some of the characteristics of both the man exerting the good effort and the man exerting the fair.

Good.—A man giving a good effort has the following tendencies. He works steadily and systematically and does not lose time doing operations foreign to the work. He takes an interest in the work he is doing and takes pleasure in turning out a good job. He works steadily at a pace which he will be able to maintain day after day and week after week. He works hard but not hard enough to endanger his health. He is conscientious about his work and, when he is not under observation, does not try to use short-cut methods which he knows will detract from the quality of the finished product.

He believes that the time-study man will give him fair treatment, and he is confident that he can more than meet the time value which will be set from the study. When the time-study man starts to time the job, the worker has all his tools at hand, and his work place is in good order. He does not try to deceive the time-study man in regard to the requirements of the job or the methods of doing it; rather does he pay no attention to the time-study man but works as if there were no one observing him.

Excellent.—An excellent effort differs from the good effort in several respects. The operator exerting an excellent effort works fast and uses his head as well as his hands. He works with a will and makes his mind direct his efforts to the best advantage. He takes a keen interest in the work. Not only does he readily follow any good suggestions which the time-study man may make, but he is also on the alert himself to better tools and methods through ideas of his own.

This worker reduces false motions to a minimum in so far as his skill permits. He thinks ahead so that he knows just what he is going to do before it is time to do it, and when the time comes, he does it with zeal. He has the utmost confidence in the time-study man and believes that he will receive just treatment at his hands. It is a pleasure to work with this man, for the time-study man feels entirely relieved of the necessity of studying the man

and can concentrate his whole attention on studying the actual job.

A man cannot keep up an excellent effort week in and week out, but he can keep it up all day and perhaps for several days. A man who usually gives a good effort will on some days, when he is feeling particularly fit, give an excellent effort. Or it may be that a keen interest in the job he is doing causes him to extend himself more than usual. More often, however, a man will give an excellent effort because of his conscientious desire to be strictly honest with the time-study man. In this case, he will not continue this effort after the time-study man has left.

Killing.—A killing effort is given by some few individuals who cannot work normally when anyone is watching them. Whether through nervousness or an inborn desire to show off, they extend themselves to a pace which they could not possibly keep up over an hour or two. Often a few quiet words from the time-study man will calm the worker down so that he will give a more rational effort. This is often advisable, for a killing effort is quite likely to affect the man's skill. From the consideration of effort alone, the killing effort is best from every standpoint but that of health.

Summary.—Again it will be advantageous to set forth the characteristics of the six kinds of effort in outline form so that they may be readily available for reference.

Poor Effort:

1. Obviously kills time.
2. Makes unnecessary trips for tools and supplies.
3. Makes two motions where one would do.
4. Fails to work systematically.
5. Has poor set-up or arrangement of work.
6. Lacks interest in work.
7. Does work more accurately than necessary.
8. Resents suggestions.
9. Purposely uses wrong or poor tools.
10. Works slowly and appears lazy.

Fair Effort:

1. Same general tendencies but of lessened intensity.
2. Accepts suggestions grudgingly.
3. Fairly systematic but does not always follow same sequence.
4. Still somewhat too accurate.
5. Makes job unduly hard.
6. Lacks confidence in the time-study man.
7. Possibly affected by late hours, dissipation, or mental worries.
8. Does not use best tools.

9. Seems purposely somewhat ignorant of the work at hand.
10. Puts some energy into his work.

Average Effort:

1. Better than fair; poorer than good.
2. Has good set-up.
3. Works steadily.
4. Plans ahead.
5. Somewhat doubts the fairness of the time-study man.
6. Works with good system.
7. Reduces lost motions.
8. Accepts suggestions but makes none.
9. Seems to hold back his best effort.

Good Effort:

1. Little or no lost time.
2. Takes an interest in the work.
3. Takes no notice of time-study man.
4. Works at best pace suited for endurance.
5. Follows a set sequence.
6. Conscientious about his work.
7. Has faith in time-study man.
8. Encourages advice and suggestions and makes suggestions.
9. Well prepared for job and has work place in good order.
10. Steady and reliable.

Excellent Effort:

1. Works fast.
2. Uses head as well as hands.
3. Takes keen interest in work.
4. Receives and makes many suggestions.
5. Reduces false motions to a minimum.
6. Works systematically to best of his ability.
7. Has utmost confidence in time-study man.
8. Cannot keep up effort more than a few days.
9. Endeavors to show superiority.
10. Uses best equipment and methods available.

Killing Effort:

1. Extends himself to pace impossible to maintain steadily.
2. Best effort from every standpoint but that of health.

Conclusion.—It is just as important for time-study men who work together to have the same standards for judging effort as in the case of skill. It is necessary to consider both skill and effort, for later the results obtained from the performance of the man studied are to be reduced to terms of average skill and average effort. Skill and effort are interdependent factors when used in determining the final results, but when they are being

considered during the time study, they should be kept carefully separated. To say that a man who gives the best effort is the man who produces the greatest amount would be utterly meaningless, because skill is not considered. A worker of poor skill might work at a killing pace and still produce only a small amount of poor-quality work. He is exerting great effort, but his lack of skill does not permit him to exert it in the right direction. On the other hand, the skilled man exerting only a fair effort would produce much more, because nearly all of his effort goes into productive motions. Similar reasoning will show that skill may not be considered alone but that the two go hand in hand in determining what a man actually does.

CHAPTER XII

COMPUTATIONS AND SUMMARY

With the observations and the information recorded, the remainder of the work necessary to complete the time study and to determine the allowed time for the job confines itself almost entirely to calculations and mathematical procedure. A good share of this work is of such a routine nature that it may be delegated to a clerk, although it must be borne in mind that accuracy is essential. On the face of the time-study sheet, alternate columns headed with T will appear blank. The figures in the columns headed with R represent the watch readings which were recorded at the terminations of the elements.

Subtractions.—The first step of the computations is to determine elemental elapsed times by subtracting successive watch readings. These subtractions are recorded in the blank columns, each one in the space between the two watch readings that determine its value. Elapsed time should be noted in ink both to insure a permanent record and to distinguish it from the watch readings.

Referring to Fig. 19 which illustrates the appearance of the time study at the completion of the observations, it will be noted that the first reading is 18, or to express the full decimal, 0.0018. The watch having been started at zero at the beginning of this element, the elapsed time will naturally be the same as the watch reading or 18 as recorded in Fig. 24 under T in column 1. Proceeding to element 2 in Fig. 24, it will be seen that the watch reading is 37. The elapsed time for element 2 is then the difference between 18 and 37, or 19, which is recorded under T in column 2. By continuing in this manner throughout the time study, subtracting each reading from the succeeding one and recording the result between the two, the elapsed time for every occurrence of each element is readily determined. Figure 24 shows the appearance of the time-study sheet after the subtractions are completed.

Variations in Sequence.—Those irregularities that called for special consideration when the observations were being recorded also demand somewhat of a variation from the usual method as just described when making the subtractions. Where a space

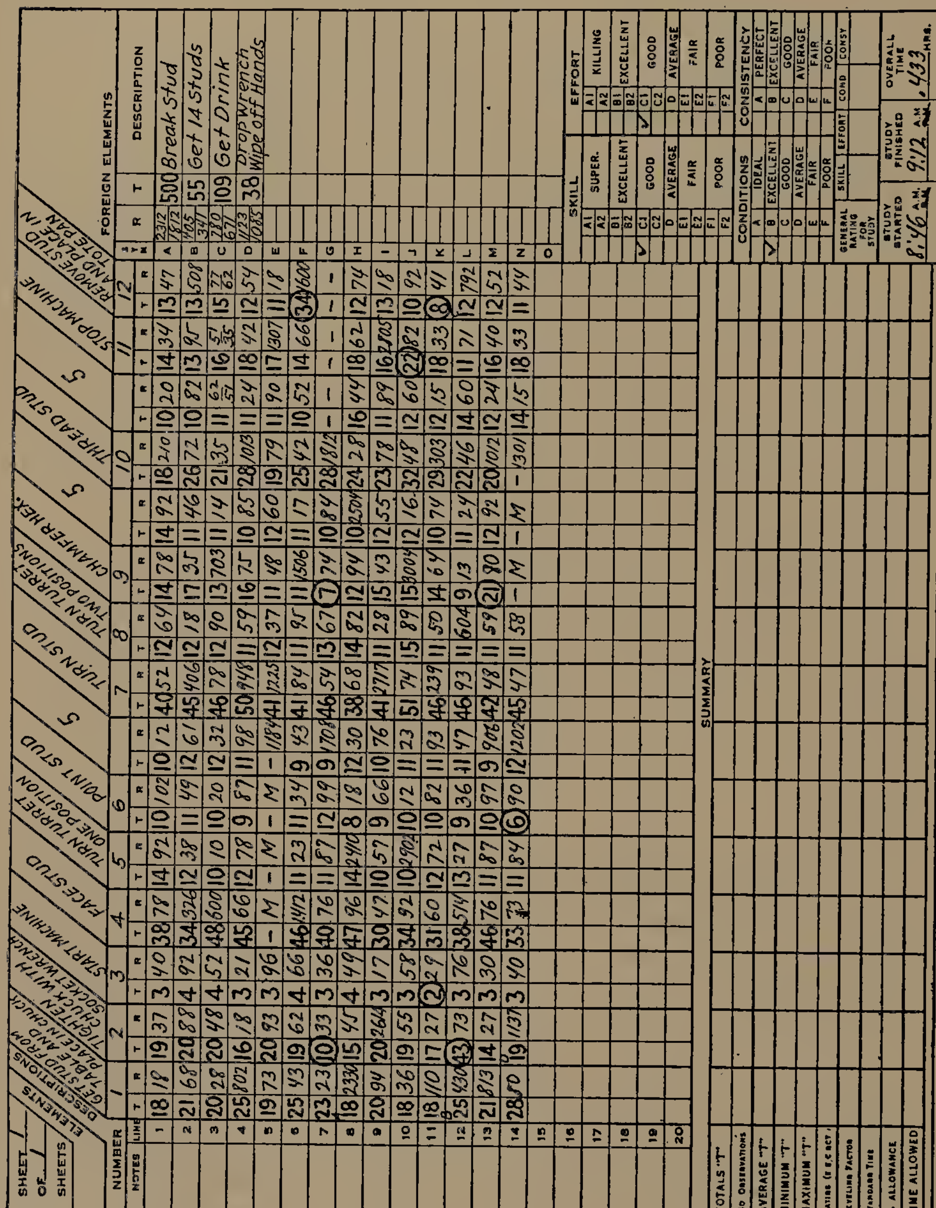


Fig. 24.—Model time study showing subtractions completed.

contains two watch readings separated by a horizontal line, the elapsed time is determined by subtracting the lower reading from the upper one. This applies to foreign elements as well as those appearing in the body of the study.

A horizontal line in a space without any watch readings indicates that the element was omitted by the operator. This element may be disregarded entirely. The elapsed time for the next completed element will be found by subtracting from the reading for this element the watch reading for the element which immediately preceded the one not performed.

An *M* indicates that the watch reading was missed by the observer. Obviously the elapsed time cannot be determined for the missed element nor for the one that follows it, so the corresponding spaces must be left blank.

When a letter indicating a foreign element is encountered, the duplicate printed symbol in the first column under Foreign Elements on the right-hand side of the sheet should be referred to. The elapsed time of the foreign element will be found by subtracting the lower reading from the upper one, and this value deducted from the total elapsed time for the regular element will leave the net or correct duration. In column 3 on line 14 in Fig. 24, a foreign element occurred. The total elapsed time for element 2 was the difference between 0.1080 and 0.1137, or 0.0057. But the *D* indicates that a foreign element must be deducted from this 0.0057. At the right under *D*, it is found that the foreign element was begun at 0.1085, the reading below the line, and ended at 0.1123, the reading above the line, giving an elapsed time of 0.0038. Deducting 0.0038 from 0.0057, the net or elapsed time for element 2 becomes 0.0019. This is recorded as shown.

Abnormal Values.—Before taking up the summary of the elapsed times, the time study should be carefully examined for abnormal values. If any are found, they should be indicated so that they can be readily distinguished and excluded from the summary. A convenient method is to circle them as shown in Fig. 24 under element 2 in lines 7 and 12. A value is regarded as abnormal when it is extremely high or low as compared to the majority of the other values for the same element. No definite rule can be established for determining when values are abnormal, because the allowable variation from normal will vary with the length of the element. For instance, in a series of 20 observations ranging in value from 0.0002 hour as the lowest to 0.0008 hour as the highest, 0.0002 hour would be abnormal if it had occurred but once and the other 19 values ranged from 0.0005 to 0.0008 hour. If, however, 19 of these values had ranged from 0.0002 to 0.0004 hour, then 0.0002 hour would be considered

normal while 0.0008 hour would be abnormal. Picking out the abnormal values is largely a matter of judgment in which there is little likelihood of error, for extreme cases will be obvious at a glance, and doubtful cases will not show sufficient variations to change the result materially whether the values are admitted to the summary or not. To illustrate this point, three examples are presented below.

Order of occurrence	*A* Elapsed times	*B* Elapsed times	*C* Elapsed times
1	8	93	2
2	11	98	3
3	9	101	4
4	22	108	3
5	10	83	3
6	8	83	4
7	10	85	3
8	11	93	3
9	10	100	4
10	10	50	2
11	9	118	3
12	6	98	3
13	9	93	3
14	14	71	5
15	8	83	5
16	9	87	4
17	9	82	6
18	8	103	4
19	10	94	4
20	9	85	3
Total............	0.0178 hour	0.1808 hour	0.0071 hour
Number of occurrences..........	19	19	20
Average..........	0.000936 hour	0.00951 hour	0.00035 hour

In example *A* the fourth value, 0.0022 hour, is obviously abnormal and is excluded at once. Closer study may raise the question as to whether the next highest value, 0.0014 hour, should be left in, and looking still further the twelfth occurrence, 0.0006 hour, may seem abnormally low. There is just about as much reason for excluding one as the other, but if they are both out, the result is not greatly changed. The total becomes 0.0158 hour instead of 0.0178 hour. This new total divided by 17, the

number of occurrences, gives an average of 0.000929 hour instead of 0.000936 hour or a decrease of seven-tenths of 1 per cent. Practically, there would be no change, for the decimal is ordinarily carried out to only four places. Hence, the result in both cases would be 0.0009 hour.

The same is true of example *B* in which the tenth value, 0.0050 hour, is obviously too low and is excluded at once. Here, as in example *A*, one might question 0.0118 hour and 0.0071 hour, which are the eleventh and fourteenth values, but by carrying out the calculations it is again found the result is not appreciably affected by taking them out. With these two values omitted, the total becomes 0.1619 hour instead of 0.1808 hour, and the average becomes 0.00952 hour instead of 0.00951 hour. By dropping the fifth decimal place, both values become 0.0095 hour.

In example *C* the first occurrence, 0.0002 hour, and the seventeenth occurrence, 0.0006 hour, are both somewhat abnormal. When they are used in the summary, the average is 0.00035 hour, and when they are omitted, the average is still 0.00035 hour.

It is better, therefore, to exclude only those values that are extreme and readily recognized as abnormal. If there are too many values discarded, the time-study man throws himself open to the possible criticism that his study is not representative of conditions as they actually were when the observations were made. There is generally a good reason for abnormal values, and the time studies of an alert and competent observer will seldom contain any, because he will have discerned and noted the causes while making the observations. Low values are frequently caused by an element being only partially performed either due to neglect of the operator, or because the condition of the material or some other feature of the job is unusually favorable for quick performance. High values are generally caused by some unusual difficulty, as a bad piece of material, or by some small foreign operation which escaped the notice of the observer and was not recorded.

Number of Occurrences.—After the abnormal values are eliminated, the next step is to count the number of occurrences for each element and record the number in the space provided under Summary at the bottom of the sheet. If more than one column has been used for an element, the values appearing in all of them should be summarized together in the first column

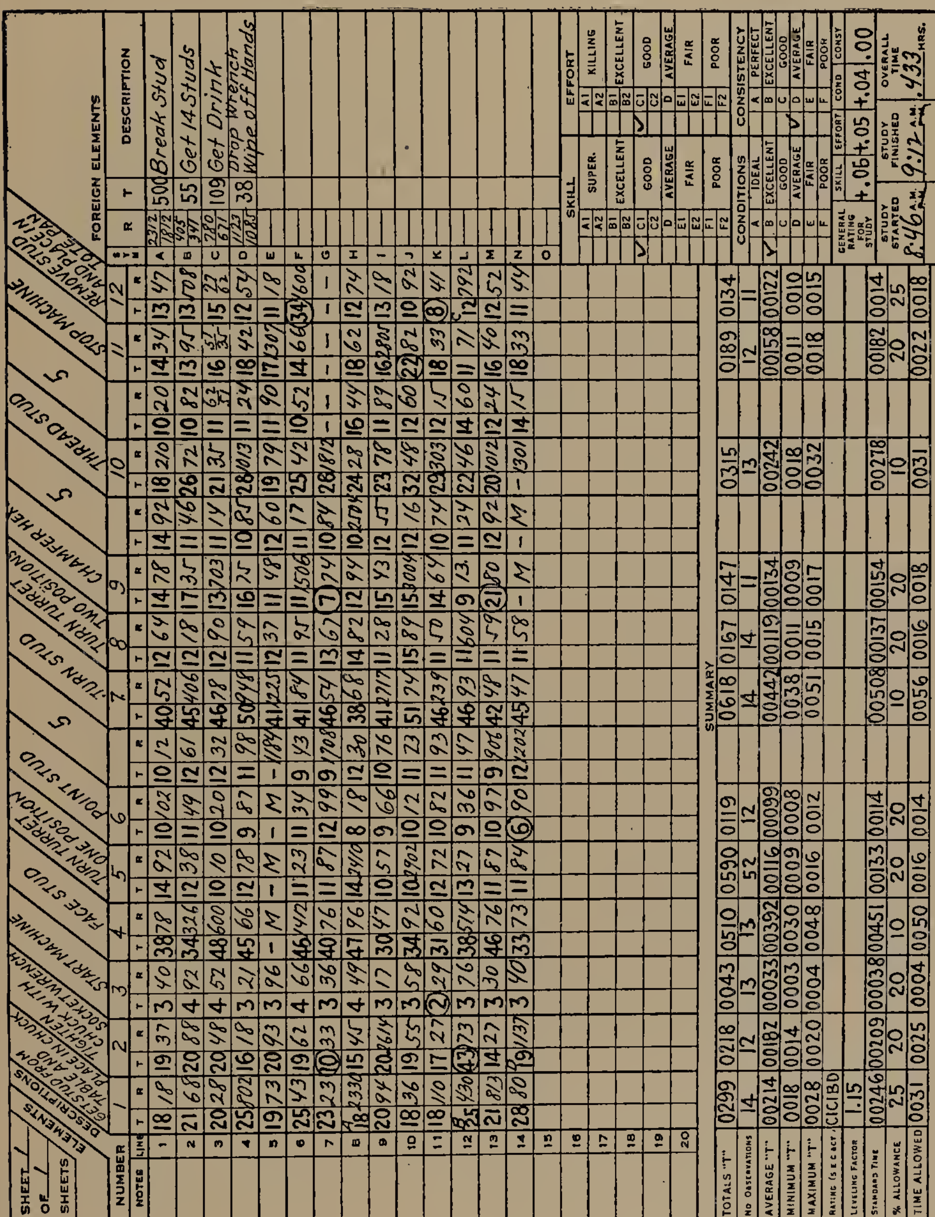
devoted to the element. This applies also to the recording of the number of occurrences. No summary will appear, then, in any of the columns to follow that have been used for the element in question, but instead of a summary there should be shown the element number appearing at the head of the summary column. It is a simple matter to recognize repetitive elements, provided the repetitions were designated at the time of observation by placing the number, which was first used to identify the element, at the tops of the columns devoted to the repeated elements.

Totals of Elapsed Times.—The time-study man himself should indicate the abnormal values, and he should also count and record the number of occurrences for each element, but the matter of adding the elapsed time for each element and finding the average elapsed time are calculations that can very well be assigned to a reliable clerk. Determining the totals of the elapsed times for each element is a comptometer or adding-machine operation. The main point to watch is that all occurrences, up to the number that has been indicated by the time-study man, have been included in the total. The full decimal, to four places, should be shown in this total, it being understood that the whole numbers expressing elapsed times indicate ten-thousandths of an hour.

Average, Minimum, and Maximum Elapsed Times.—The totals of the elemental elapsed times should be divided by the number of occurrences as recorded by the time-study man. The results are the average elapsed times which may be taken to represent the performance level of the operator on that particular study. To these average elapsed times are applied the appropriate leveling factors in order to arrive at the standard times. For example, in Fig. 25, the total of the elapsed times for element 1 was 0.0299 hour. This divided by 14, the number of times that element 1 occurred in the whole study, gave an average elapsed time of 0.00214 hour. Since this average time is to be multiplied by a leveling factor and then increased by an allowance percentage, it is well, for the sake of accuracy, to carry as many places as can be conveniently read on a slide rule. The final time value or the allowed time for each element need be given only to the nearest fourth decimal place.

By glancing over the list of elapsed-time values, the minimum or lowest time in which each element was performed is readily apparent. These values should be recorded on the fourth line

of the summary. Likewise, the maximum values should be selected and recorded on the fifth line. These values are not actually used to determine the final allowed time, but they are



Elements	1 Get stud from table and place in chuck	2 Tighten chuck with socket wrench	3 Start machine	4 Face stud	5 Turn turret one position	6 Point stud	7 Turn stud	8 Turn turret two positions	9 Chamfer hex	10 Thread stud	11 Stop machine	12 Remove stud and place in tote pan
Totals "T"	0299	0218	0043	0510	0590	0119	0618	0167	0147	0315	0189	0134
No. Observations	14	12	13	13	52	12	14	14	11	13	12	11
Average "T"	00214	00182	00033	00392	00116	00099	00442	00119	00134	00242	00158	00122
Minimum "T"	0018	0014	0003	0030	0009	0008	0038	0011	0009	0018	0011	0010
Maximum "T"	0028	0020	0004	0048	0016	0012	0051	0015	0017	0032	0018	0015
Rating (S E C Cy)	C1C1BD											
Leveling Factor	1.15											
Standard Time	00246	00209	00038	00451	00133	00114	00508	00137	00154	00278	00182	0014
% Allowance	25	20	20	10	20	20	10	20	20	10	20	25
Time Allowed	0031	0025	0004	0050	0016	0014	0056	0016	0018	0031	0022	0018

Foreign elements:

Sym.	R	T	Description
A	2312 / 1812	500	Break Stud
B	405 / 341	55	Get 14 Studs
C	780 / 671	109	Get Drink
D	1123 / 1085	38	Drop Wrench / Wipe off Hands

General rating for study: Skill +.06, Effort +.05, Cond. +.04, Consy. .00

Study started 8:46 A.M. Study finished 9:12 A.M. Overall time .433 hrs.

FIG. 25.—Model time study showing summary and computations of elemental allowed times completed.

convenient for reference purposes, and too great a difference in them may justify further investigation.

Levelinff Factor.—The factor by which the average time is multiplied in order to determine standard time is called the

leveling factor. The value of this factor is influenced by four things: skill, effort, conditions, and consistency. By referring to the lower right-hand corner of the sheet, the general rating of these four points will be found. Except for those elements

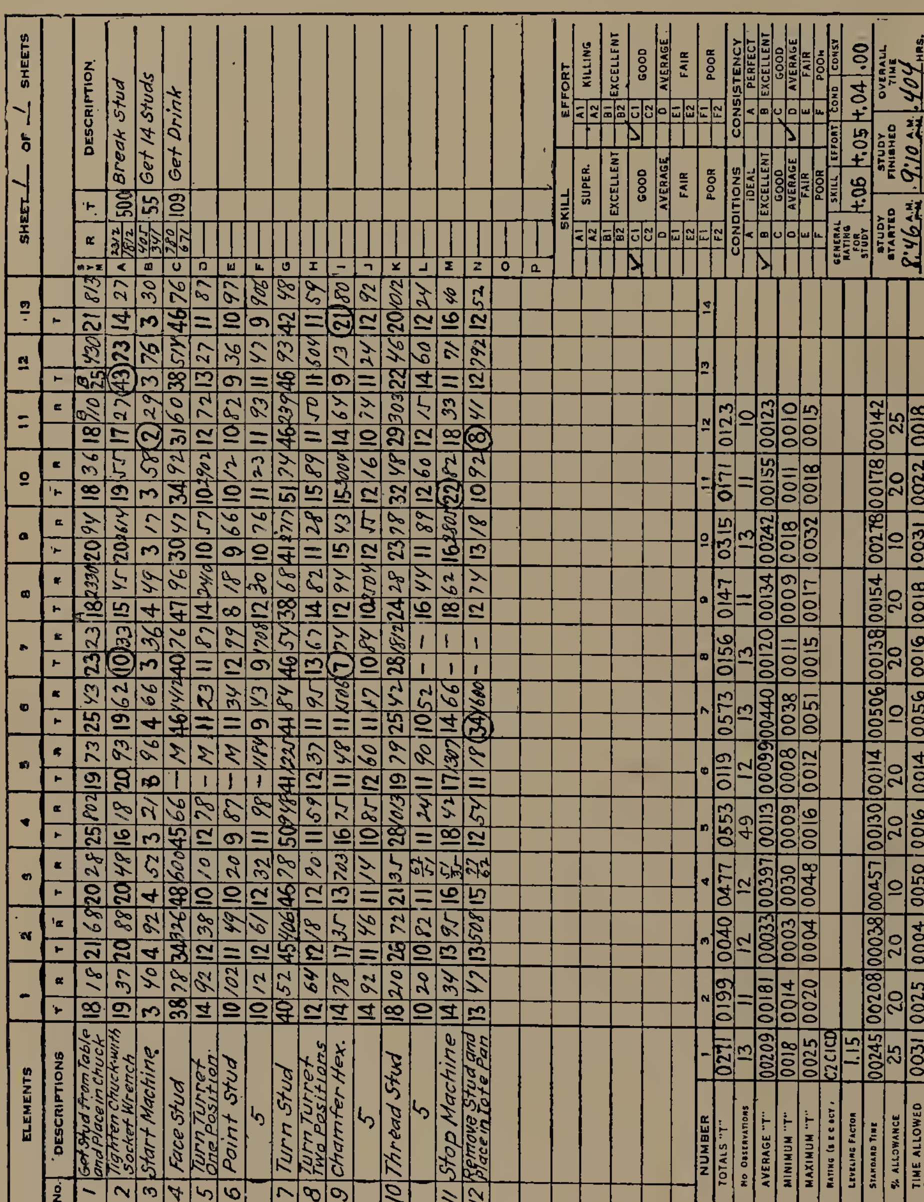


FIG. 26.—Model time study as it would appear on a form of the vertical column type, showing the same data as that shown in Fig. 25 except that there are but 13 instead of 14 observations.

that have been individually rated, this general rating will be used for the entire study. Exceptions will have been indicated in appropriate columns in the seventh line of the summary. Each symbol used to express this rating has a corresponding

numerical value as shown on the Performance-rating Table (see Fig. 27). The algebraic sum of these numerical values added to 1.0 will give the leveling factor which should be recorded in the space reserved for that purpose. If a general rating has

Skill			Effort		
+0.15	*A*1	Superskill	+0.13	*A*1	Killing
+0.13	*A*2		+0.12	*A*2	
+0.11	*B*1	Excellent	+0.10	*B*1	Excellent
+0.08	*B*2		+0.08	*B*2	
+0.06	*C*1	Good	+0.05	*C*1	Good
+0.03	*C*2		+0.02	*C*2	
0.00	*D*	Average	0.00	*D*	Average
−0.05	*E*1	Fair	−0.04	*E*1	Fair
−0.10	*E*2		−0.08	*E*2	
−0.16	*F*1	Poor	−0.12	*F*1	Poor
−0.22	*F*2		−0.17	*F*2	
Conditions			**Consistency**		
+0.06	*A*	Ideal	+0.04	*A*	Perfect
+0.04	*B*	Excellent	+0.03	*B*	Excellent
+0.02	*C*	Good	+0.01	*C*	Good
0.00	*D*	Average	0.00	*D*	Average
−0.03	*E*	Fair	−0.02	*E*	Fair
−0.07	*F*	Poor	−0.04	*F*	Poor

Fig. 27.—Performance rating table.

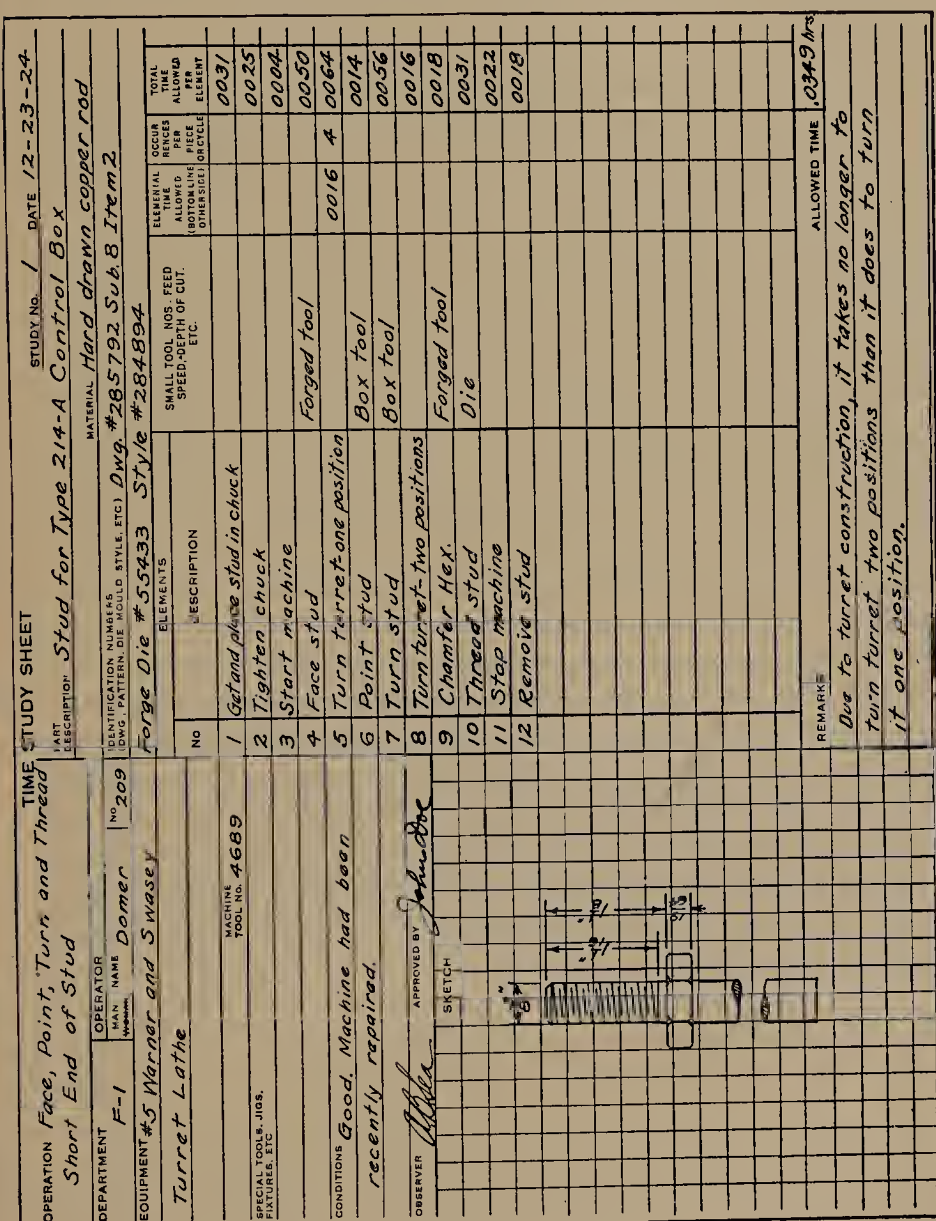
been applied to the entire study, there will be, of course, a general leveling factor. In this case, it is not necessary to record it for every element. The examples given on the following page illustrate the method of arriving at the leveling factor.

Performance rating	Numerical equivalents	Sum to be added to 1.0	Leveling factor
Excellent skill Good effort Average conditions Good consistency *B*2, *C*1, *D*, *C*	+0.08 + 0.05 + 0.00 + 0.01	0.14	1.14
Average skill Excellent effort Good conditions Good consistency *D*, *B*1, *C*, *C*	+0.00 + 0.10 + 0.02 + 0.01	0.13	1.13
Excellent skill Poor effort Good conditions Fair consistency *B*1, *F*1, *C*, *E*	+0.11 − 0.12 + 0.02 − 0.02	−0.01	0.99
Poor skill Good effort Average conditions Poor consistency *F*1, *C*1, *D*, *F*	−0.16 + 0.05 + 0.00 − 0.04	−0.15	0.85
Average skill Fair effort Average conditions Fair consistency *D*, *E*1, *D*, *E*	0.00 − 0.04 + 0.00 − 0.02	−0.06	0.94
Average skill Average effort Average conditions Average consistency *D*, *D*, *D*, *D*	0.00 + 0.00 + 0.00 + 0.00	0.00	1.00

Standard Time.—At this point, the leveling principle which is explained in detail in the next chapter is applied. As previously explained, the average time represents the actual performance level and includes, in the aggregate, all of the effects of variations from normal skill, normal effort, normal conditions, and normal consistency. Each average elapsed time is multi-

plied by the appropriate leveling factor, and the result is recorded in the eighth line of the summary.

Allowances.—If workers were able to work continuously, standard time would be the correct value to allow, but constant



TIME STUDY SHEET

OPERATION Face, Point, Turn and Thread Short End of Stud

STUDY No. 1 DATE 12-23-24

PART DESCRIPTION Stud for Type 214-A Control Box

MATERIAL Hard drawn copper rod

DEPARTMENT F-1

OPERATOR: MAN NAME Domer; No 209

IDENTIFICATION NUMBERS (DWG., PATTERN, DIE MOULD STYLE, ETC.) Dwg. #285792 Sub. 8 Item 2 Forge Die #55433 Style #284894

EQUIPMENT #5 Warner and Swasey Turret Lathe

MACHINE TOOL No. 4689

SPECIAL TOOLS, JIGS, FIXTURES, ETC.

CONDITIONS Good. Machine had been recently repaired.

OBSERVER

APPROVED BY

SKETCH

ELEMENTS No	DESCRIPTION	SMALL TOOL NOS., FEED SPEED, DEPTH OF CUT, ETC.	ELEMENTAL TIME ALLOWED (BOTTOM LINE OTHER SIDE)	OCCURRENCES PER PIECE OR CYCLE	TOTAL TIME ALLOWED PER ELEMENT
1	Get and place stud in chuck				.0031
2	Tighten chuck				.0025
3	Start machine				.0004
4	Face stud	Forged tool			.0050
5	Turn turret-one position		.0016	4	.0064
6	Point stud	Box tool			.0014
7	Turn stud	Box tool			.0056
8	Turn turret-two positions				.0016
9	Chamfer Hex.	Forged tool			.0018
10	Thread stud	Die			.0031
11	Stop machine				.0022
12	Remove stud				.0018
				ALLOWED TIME	.0349 hrs

REMARKS Due to turret construction, it takes no longer to turn turret two positions than it does to turn it one position.

FIG. 28.—Model time study showing back of sheet completely filled out.

application to the job is neither possible nor desirable. In the course of a day, there are bound to be occasional interruptions and delays, for which due allowance must be made in establishing the time value. These allowances are determined by the time-

study man in accordance with the methods set forth in a succeeding chapter. Each element should be considered separately and the appropriate allowance recorded in the next to the last line in terms of a percentage by which the standard time is to be increased.

Time Allowed.—The time allowed for each element is recorded in the last line of the summary in decimal hours. It is the result after the standard time has been increased by the allowance percentage. This value becomes a part of the allowed time for the operation as calculated on the back of the sheet.

Back of Time-study Sheet.—The numbers and descriptions of the elements should be transcribed in ink on the back of the sheet. The majority of future references will be made to this part of the time study. Descriptions of the elements may be elaborated upon if it will add to the clearness. It is well at this time again to check briefly the information and the sketches to see that everything is as complete as possible. The time allowed for each element is transcribed to the column reserved for that purpose. In the next column to the right should be noted the number of times the element occurs on one piece or cycle of the operation. Extensions of the total time allowed for each element should be made and recorded in the last column. Elements that occur but once will be carried over as they appear in the Time Allowed column. The time allowed for those occurring more than once will be multiplied by the number of times they occur and the product carried over. The allowed time for the operation is then the sum of the items in the last column. Figure 28 shows the model time study with the back of the sheet completely filled out. A full discussion of Allowed Time will be found in Chap. XV.

CHAPTER XIII

DETERMINATION OF STANDARD TIMES BY LEVELING

Assuming that the observations have been made accurately, the most important step in time-study procedure is the determining of the standard time. The standard time which is established from a time study taken on any job should be the time that is required by an operator who possesses average skill and training when he is working at an average pace under average conditions. In establishing the standard time, the greatest care and judgment must be exercised, for at this stage everything which influences the time values must be taken into account. The experienced observer, who is acquainted with the character of the work and with effective and efficient methods of performing simple manual and mechanical operations and who is also a keen student of human nature, will soon learn to recognize with certainty any tendency on the part of the operators to do other than that which should be expected of them and to make allowances accordingly.

Reasons for Leveling.—Considering, then, that different operators possess varying degrees of skill and that they will differ in the effort given, in order that the time standard established from a time study for any degree of skill or effort may be a true standard on the basis of an average operator, it is necessary to use some method of adjustment of the recorded elemental times to arrive at a time standard. It is evident if, on the basis of an operator whose skill is good and who has put forth a good effort, a time standard were established such that he could just meet it or gain on it slightly, that the less skilled operator would fail to meet it even though he would put a good effort into his work. Or, on the other hand, assume that the time standard is established without taking skill and effort into account from a study taken on a less skilled operator who gave only a fair effort. Then he will just meet this time, but when he improves his effort, he will gain on or beat the time to an extent to which he is hardly entitled, and the time will be far too liberal for the more skilled operator.

This can be best illustrated by a simple example. Assume that two men, working as molders in a foundry, are molding the same part, there being two patterns for the job. The time-study man studies both operators on the same number of molds, and he finds that one operator is much more skilled than the other and that the more skilled operator gives the better effort. Consequently, there is a large difference in the time taken by each to make the same number of molds. The questions are: Which time study should be used and how could a time value be arrived at from either study which would be correct for both operators? The answer is that there must be some method of bringing the results obtained from both operators to the same level, some method which will bring about the same results that would be obtained if there were no difference in skill and effort of operators. Without some such method, time study would be of little value as a means of setting accurate time standards. With a method of adjustment of the elemental elapsed times, it really does not matter which study is used or whether one or ten studies have been taken, for it is expected that the trained observer will establish the same time standard regardless of the type of operator he has studied. The extent to which the observer can accomplish this is, of course, dependent on the accuracy and the thoroughness of the method used.

Various Methods of Adjustment.—There are several methods used to take into consideration the skill of the operator, the effort given during the time study, and the conditions under which the operation is performed. Each of these methods has the same end in view, that is, the establishing of correct standard times. They are, however, based on different principles, and hence the results which will be obtained by using one method will, in all probability, not agree with those obtained by using another. Since there is this disagreement, some of these methods must be founded on incorrect assumptions.

Some of the more commonly used methods are the percentage-selection method, the performance-curve method, the variation method, the straight-average method, and the leveling method. Of these, the leveling method is the most scientific and the most accurate yet devised.

Percentage-selection Method.—The percentage-selection method is one of the more popular adjustment methods. While making his observations, the time-study man judges, in a general way, the

skill and effort shown. He then decides on a percentage to use in making his selections, basing his decision upon his judgment of what this should be for the particular skill, effort, and conditions he has studied. He makes a summary of the time values for each elemental operation, arranging them in order of magnitude with the smallest first and noting the number of times each value occurred.

From these summarized values, the time-study man selects the value which is considered the standard time by using his percentage selection factor. This factor multiplied by the total number of readings for a given element gives the number by position of the reading to be chosen; that is, if there are ten readings and a factor of 40 per cent has been determined, 0.40×10 or the fourth reading will be the value selected.

The range of selection for the average operator working under good conditions will normally be between 30 and 50 per cent. For conditions above or below average, the selection factor will increase or decrease proportionately.

The value of this method depends upon the accuracy of judgment by which the percentage-selection factor is determined. This method is highly empirical, but at the same time, usable results may be obtained. Under this method, it is not possible always to determine the same standard time for a given element when different grades of operators are studied, for it is not likely that the correct standard-time value will occur in every study taken. All of the values obtained from a study on a man giving a poor effort with poor skill may be higher than the true standard-time values, and those obtained from the excellent effort of a highly skilled operator may be lower. From neither of these studies, then, could the true standard-time value be found regardless of the accuracy with which the percentage of selection was determined.

Performance-curve Method.—The performance-curve method differs from the percentage-selection method in the manner of determining what factor to use. A curve is plotted for one or more representative elements of the study. Each curve is plotted in a square, the abscissas being the elapsed-time values ranging from the lowest to the highest and the ordinates being the cumulative percentages of the total number of observations.

For example, assume that a time-study man has taken a study on the drilling of 50 cast-iron brackets. The first element of the

operation is "pick up part" and the time for this element ranges from 0.0030 to 0.0040 hour as follows:

Number of Occurrences	Elapsed Time
1	0.0030
7	0.0032
18	0.0033
18	0.0034
5	0.0035
2	0.0040

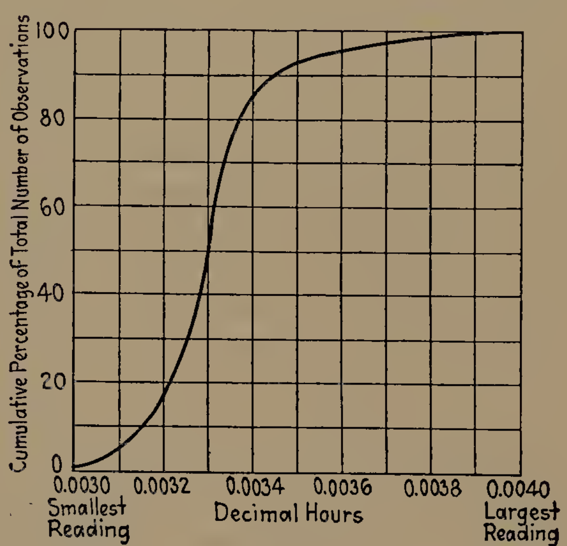


FIG. 29.—Performance curve for determining percentage selection.

The curve for this element is plotted as shown in Fig. 29. It will be noticed that part of this curve is quite flat, as will always be the case. The time values which make the flat part of the curve are considered to be consistent time values, and those which make the greater curvature at either extreme are considered to be abnormal values and hence are discarded.

A straight line is drawn along the flat part of the curve to aid in determining just where the greater curvature begins. In the case under consideration, the flat part of the curve is found to be between the ordinates 30 and 70. The percentage number of observations is found on the ordinate which bisects the flat part of the curve or the 50 per cent ordinate. Thus, 50 per cent is the selection factor determined, and the procedure from this point on is the same as in the first case considered. If the element which has been used to plot the performance curve is

considered to be representative, 50 per cent selection is used throughout the study.

The percentage-selection factor is determined by this method wholly on the basis of consistency. It takes no account of skill, effort, and conditions, or perhaps assumes that the better these three factors are, the closer will be the consistency. That is not necessarily true. One may work slowly and evenly, and the results obtained from a study taken on him will be highly consistent. Another man may work very quickly and with his best effort. The very fact that he is hurrying will tend to interfere with the evenness of his motions, and the resulting elapsed times might vary greatly. But the slower man would be given the higher percentage selection.

When consistency is used alone as the basis of determining standard times and an operator realizes this, he is able to secure ridiculously high time values for himself by being consistently slow. A case occurred where a study was taken under this system on an operator sawing slots in a commutator. The operation consisted mainly of pushing a power saw through by hand, pulling it back, and turning the commutator by an indexing device. These three elements repeated again and again comprised about 95 per cent of the operation. The operator, while he performed each element slowly, mentally counted. Thus he was able always to take the same amount of time to do the element, and the result was a study nearly perfect from the standpoint of consistency. After the time value for the job was established by the performance-curve method, it was found that the operator gained on the value by 300 per cent. If the adjustment method had required that effort be taken into consideration, the time-study man would have seen at once that the operator was giving a poor effort and would have taken that into account in setting the time value.

Variation Method.—The variation method is another adjustment method also based on consistency. After the subtractions have been made, abnormal values are discarded, and the remaining values for each element are averaged. Each average time is divided by each corresponding minimum, and the quotient is called the variation factor. These elemental variation factors are averaged, and each average time value is divided by the average variation factor. The resulting values are considered to be the elemental standard times.

The variation factor will vary as the consistency of the individual times vary. If the consistency is perfect, the average variation factor will be 1.00. This will mean that the standard time is the time that the man actually takes. It can never be higher, regardless of skill and effort, and practically, it is always lower.

Straight-average Method.—Another less used method is the straight-average method. In this method, the average of actual performance is found after abnormal values have been discarded. This method does not even take consistency into account and is practically valueless unless an average operator is studied under average conditions.

The Leveling Method.—Suppose, for a moment, that it is possible to find an average man working on an operation which the time-study man wishes to study. This man will possess average skill and will work with an average effort. Assuming that conditions are average, the times for each element of the operation obtained from a study of this man will be the standard times which it is desired to determine. The study will be taken on a number of pieces, and while the time value determined for a given element will not be exactly the same for every piece because of minor differences impossible to detect, the average of these times, after abnormal values have been set aside, will give the standard time for that element which the operator may be expected to meet consistently. In other words, the average will determine the plane along which the operator possessing average skill will continuously work while giving an average effort. The standard-time values for all operations in the plant should be along this plane.

In most cases, however, it will not be possible to find an average man. Suppose, rather, that it is necessary to study a man who, although working with an average effort, possesses good skill. Because of this higher degree of skill, the average elemental time values determined from the study will be lower than those obtained from the average man. This second man will work along a higher plane than will the average man.

Similarly, if another man, working with an average effort but possessing only fair skill, be studied, the time values obtained will be higher than those of the average man, for this man will be working on a plane below the average. These levels are shown graphically in Fig. 30. The standard-time values as set from

the time study should lie along the performance level AB, since this will allow the average man just to meet the established time. In the last two cases considered, the level obtained does not coincide with the level AB because these two operators differed from the average operator in respect to skill.

Again, consider three operators all of whom possess average skill, but when working under average conditions, exert varying degrees of effort. If one man is an average man and hence is exerting an average effort, his average plane will be along AB. If the second man exerts a good effort, he will perform the operation faster than the first man will, and his performance level will be relatively higher. Lastly, the third man exerting only a fair effort will be working along a plane lower than AB.

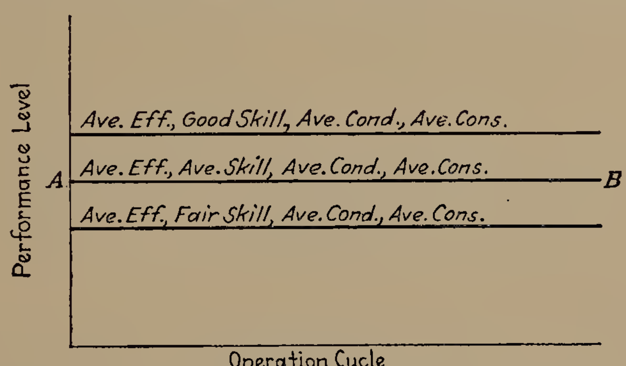


FIG. 30.—Graphical representation of performance level.

Varying conditions will also affect the performance level. If two men are working under different conditions, even though they both have the same skill and give the same effort, the one working under the more unfavorable conditions will perform along a lower plane than the other.

It has been said that minor variations impossible of detection will cause the elapsed time for a given element to vary slightly when it is done a number of times. If this is slight, and the average time value does not differ greatly from the two extremes, the variation may be attributed to the inability of a human being to work with exact clock-like regularity, and the fact that the stop watch is read to only the nearest one-hundredth division of the dial. Where the variation is greater, there is undoubtedly something which, although impossible of detection, materially influences the performance of the work. Usually it is a deviation by the operator from this exact plane of work. This deviation

is so small that it does not justify considering that skill, effort, or conditions have changed. These, while ranging from a minimum to maximum in a series of minute steps, are practically divided into only a few steps. Thus a slight deviation would not be great enough to change the degree of skill, effort, or conditions from one class to another. At the same time, the readings show that there has been a change, and hence the average time value will be affected. This variation is called the consistency with which the operator works. The greater the consistency, the more nearly right will be the average value for the particular plane in which the operator performs. Thus it is seen that consistency must also be considered during the leveling process.

These four variables—skill, effort, conditions, and consistency —all influence the level at which the operator works. The first three are determined during the actual making of the time study. The last is determined after the subtractions have been made. These four together determine definitely along what performance plane any operator works at any time. When this plane has been located, it is a simple mathematical process to bring the time values determined from any study down or up to the desired standard-time values.

Determination of Level.—When skill, effort, conditions, and consistency have been determined, the next step is to find the exact level which these four factors locate. This may be done with the aid of either the Performance-rating Table shown in Fig. 27 or the Performance-rating Chart (Fig. 31). The Performance-rating Table gives numerical values which when added together algebraically give the proper leveling factor to use for any given combination of the four variables. Under each different degree of skill and effort excepting "average," two numerical values are given. For example, under superskill, the values +0.15 and +0.13 are given. In the column immediately adjoining, the symbols A_1 and A_2 are shown. These symbols correspond to those given on the face of the time-study form. The symbols bearing the subscript 1 refer to degrees of skill or effort which are slightly better than those described by the definitions given in Chaps. X and XI but which are still somewhat below the standards set for the next highest subdivision. Similarly, the symbols bearing the subscript 2 refer to slightly poorer degrees of skill or effort than those given by the definitions. A_1, then, in the skill column designates a skill outstanding in every

respect, while A_2 refers to a degree of skill which, while better than excellent skill, is on a par slightly below that described by the definition of superskill. Midway between the two falls the degree of skill given by the definition, and the numerical figure

Conditions			Consistency		
+0.05	A	Ideal	+0.04	A	Perfect
+0.04	B	Excellent	+0.03	B	Excellent
+0.02	C	Good	+0.01	C	Good
0.00	D	Average	0.00	D	Average
−0.03	E	Fair	−0.02	E	Fair
−0.07	F	Poor	−0.04	F	Poor

To determine Leveling Factor add algebraically values from above table to factor read from curves below.

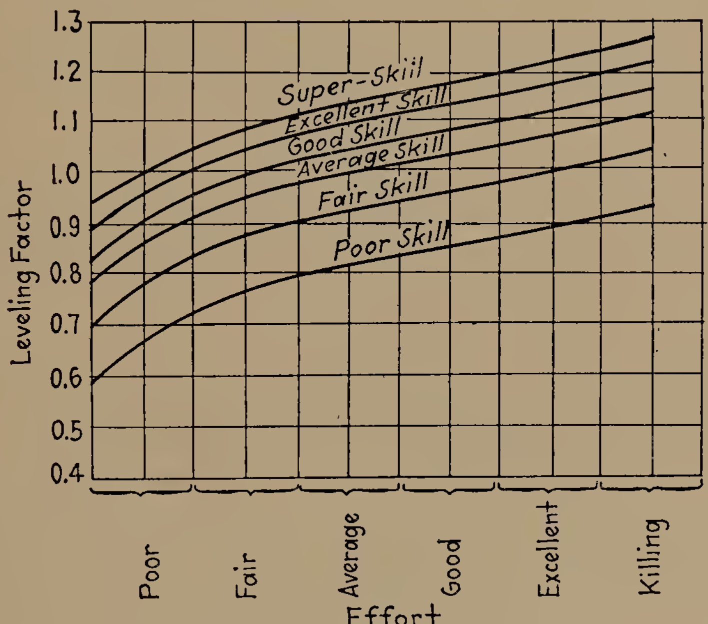


FIG. 31.—Performance rating chart.

used is the average of the two given in the table. In the case of superskill this is the average of +0.15 and +0.13, or +0.14.

At the time of taking the study, the time-study man records his judgment of the skill and effort exhibited by the worker on the face of the time-study form. This he does by placing a check mark opposite the proper symbol. If the operator works with an

effort which is slightly better than fair and shows average skill, the time-study man will place a check mark opposite E_1 in the effort column and opposite D in the skill column. If the effort exactly corresponds with that designated by the standard definition, the time-study man should circle both the subscript 1 and 2 letters, thus indicating that the average of the two values given in the Performance-rating Table is to be used. This method of considering degrees of skill and effort slightly above or below those given by the definitions makes it possible to rate an operator as closely as human judgment permits.

The Performance-rating Chart (Fig. 31) shows graphically the relation between skill and effort and illustrates clearly the fundamental principles upon which the leveling method is based. "Effort" is used as the base against which the leveling factor as determined by skill and effort alone is plotted for each of the six degrees of skill. For the sake of clearness, curves of degrees slightly above or below those considered as standard are omitted. The effect of conditions and consistency on the leveling factor as determined from the curves is given by the table at the top of the chart.

The Performance-rating Table and the Performance-rating Chart are, of course, interchangeable. The chart is slightly more flexible, while, on the other hand, values may be determined from the table with greater exactitude. Thus, it will be found that the table is better for everyday use.

The chart, however, illustrates more clearly the following basic principles. For a given effort, a man's output will vary as his skill, and for a given degree of skill, his output will vary with the effort expended according to the Law of Diminishing Returns; that is, up to a certain point, return is proportional to expenditure, but beyond that point, the addition of another unit of expenditure will bring a lesser return than did the preceding unit. Applied to effort, performance level for a given degree of skill will be very nearly proportional to the effort expended except that in the lower stages of effort, one unit of increase in effort will raise the performance level more than will a similar unit of increase in the higher stages of effort.

On the chart, the lines of skill are plotted according to the Law of Diminishing Returns, and these lines are also spaced according to this law. Thus, the difference in level caused by changing from poor to fair skill is greater than that caused by changing from good to excellent skill.

The paths of the curves given on the chart were determined from a number of time studies taken under varying conditions on men who differed in skill and effort. For example, the difference between a man working under average conditions with a good effort and possessing fair skill and a man under poor conditions showing average effort with good skill was accurately determined by studying each when doing exactly the same operation of drilling two holes in an iron casting. Similar studies were taken over work ranging from cleaning rough castings to complex coil building, and thus the curves are truly representative.

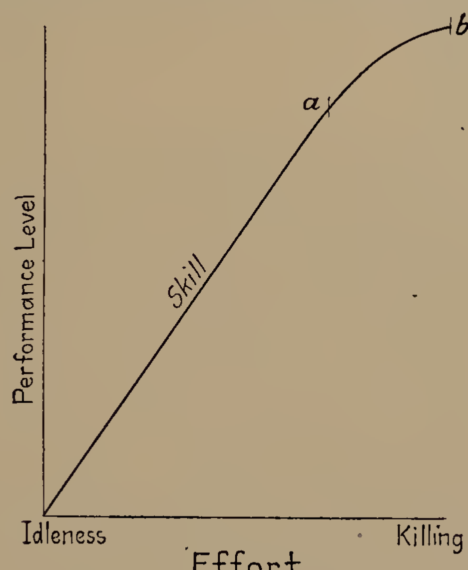


FIG. 32.—Curve showing variation of performance level over complete range of effort for a given degree of skill.

The curves which are shown on the chart are only those portions of curves which are usable for time-study purposes. Actually, there are many degrees of effort worse than that defined as poor. The worst effort possible would, of course, be exhibited by the operator who stands in idleness doing no useful work. From this effort, there is a considerable range before the poor effort is reached. Thus, for example, the complete curve of average skill would appear as in Fig. 32. For time-study work, only the portion *AB* is considered. Care must be used to make sure that any operator studied meets at least the definition of poor effort. Similar reasoning holds true in the case of skill.

Number of Pieces Studied.—The greater the number of pieces that are studied, the greater will be the number of elapsed-time

readings obtained for each element, and hence the more truly representative will be the average elapsed-time value obtained. Thus, in every case, it is desirable to study as many pieces as possible.

An actual time study on core making gave the following elapsed-time values for the element of rap core box, for 16 pieces:

0.0020	0.0014
0.0014	0.0014
0.0014	0.0015
0.0011	0.0018
0.0013	0.0012
0.0020	0.0019
0.0020	0.0012
0.0020	0.0011

If only one piece had been studied, the elapsed-time value would have been the first, or 0.0020. If five had been studied, the average elapsed-time value would have been 0.00144. If 10 pieces had been studied, the average value would have been 0.00156. Actually, on the 16 pieces studied, the average elapsed-time value was 0.00152. It is readily seen that the first value is not representative. The first five values give a better value, but there are still too few readings to justify absolute confidence in the accuracy of the average value. Ten readings give a truly representative value which is changed only very slightly by the study of six more pieces. In fact, the change is hardly great enough to warrant the extra time and work involved in securing the additional data. This bears out what was said under Observations concerning the influence of the Law of Diminishing Returns on the number of pieces studied.

If the level has been accurately determined, the total standard time as determined from a study on one piece should not differ greatly from that obtained from a study on 10 pieces. The element standard-time values will vary, however, for while some are close to what would be obtained from averaging 10 pieces, others are higher or lower. It is important that all elemental-time values should be truly representative if the study is to be used later for formula construction.

The leveling method is the only method of those discussed by which it is possible to take skill, effort, and conditions into account when the study is made on only one piece. Under all other methods, the actual readings must be taken as the true

standard times although they obviously are not unless the operator studied is average. Thus, if there is only one piece available for study or if the time-study man is exceedingly pressed for time, it is possible to get a usable study from one piece. Because, however, of the variation in elemental-time values just mentioned and because of the difficulty of determining accurately at just what level the operator is working during the short time when the study is being made, it is recommended that the practice of studying only one piece be avoided whenever possible.

Variations in Level during One Operation.—An operator may not always work at the same level throughout the entire time

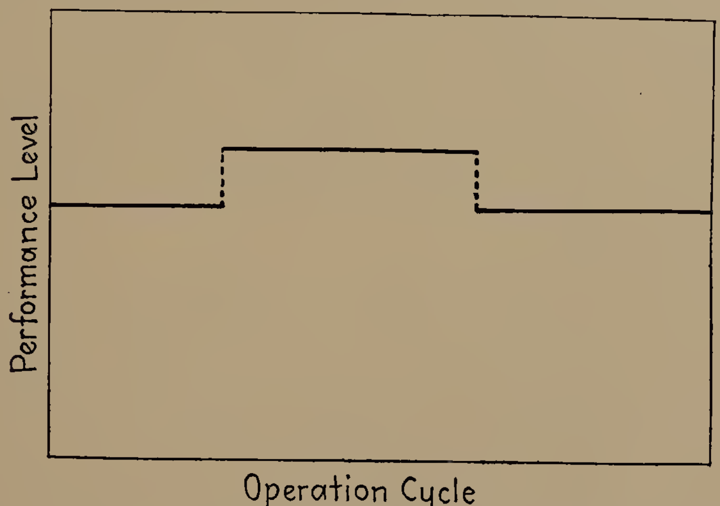


Fig. 33.—Graphical representation of variation in performance level during operation cycle.

study, particularly if the operation is long. If the study lasts all day, the man may slow up during the afternoon because of fatigue. It may be that on a comparatively new job, an operator shows only average skill during the first and the last parts of the operation, but during the middle part, because it is similar to an operation he has performed many times before, he shows good skill. In this case, his performance level during the whole operation will be as shown in Fig. 33.

Wherever there is a change in level due to any condition, the time-study man should note it at the time and the operation affected by it. Later when he is working up his time study, he can change his percentage-leveling factor as is necessary.

CHAPTER XIV

ALLOWANCES

An allowance is extra time which is added to the standard time to care for various items which require the operator's time and which are not a regular part of any one job. The determining and making of correct allowances is a very important step in time-study work. The time-study man will be called upon by the supervisory force as well as by the operators to answer questions as to how this or that thing is taken care of. In order that he may be in a position to answer such questions intelligently, he must make a thorough study of the conditions surrounding the job to determine the kind and amount of allowances he must make.

When the time study is taken, time for performing all foreign operations is deducted. The workers often question the justice of this since they realize that some of the delays, although not strictly a part of the job, are entirely unavoidable. The time-study man should be able to explain clearly that the purpose of the study is to determine the standard time for the performance of the job, exclusive of everything that is not a regular element of the operation, and that all necessary and unavoidable delays are considered in allowances which are added to the standard time to arrive at the allowed time. Sometimes it is well to go into detail and explain how allowance percentages are determined, and in addition, show the amount of allowance which is made for each delaying factor.

Necessity for Allowances.—The necessity for making allowances should be apparent from the fact that it is not practicable to allow time on individual jobs for human delays, minor breakdowns, and other irregularities which cannot be foreseen. Even if it were possible to do so, it would not be desirable, as it is better to distribute in equal proportion such time to every job or operation performed.

An operator cannot be expected to work steadily all day without delays from some cause, even if his physical condition were such that he could maintain a good effort of performance all day

long, day in and day out, without affecting his health. Human requirements, minor breakdowns, and other irregularities which cannot be foreseen would interfere. The situation of a worker in industry may be compared with that of a man making his first long journey by automobile. He may plan to motor from Pittsburgh to Chicago, a distance of approximately 500 miles. In trying to determine how long it will take to cover the distance, he reasons that if he holds a speed of 35 miles per hour, he should make the trip in 500 ÷ 35, or approximately 14 hours. Theoretically, this is correct, but after the trip is completed, the motorist finds that it has taken 20 hours. In trying to discover where he lost the time, he reviews the journey from the beginning and recalls several necessary stops he had to make for various reasons. He decides, that in the future when planning a trip, he will have to make allowance for necessary and unavoidable delays. So it is with workers. An operator, experienced on a certain operation and giving a good effort, will find that he performs the operation in 10 minutes. If he works an 8-hour day, he should complete $(8 \times 60) \div 10$, or 48 pieces. At the end of the day, however, he always finds that he is a certain percentage short of this amount, and upon reflection, reasons that this cannot be avoided, for there are several things that interfere with his constant performance which cannot be eliminated. This condition makes it necessary to study and determine just how much must be added to the standard time to allow for time lost due to necessary and unavoidable delays. The making of correct and accurate allowances is just as important as the determining of the correct standard time, for it is evident that if a value which is correct is added to one that is incorrect, the result will be incorrect, and the resultant wrong time values will destroy the confidence and cooperation of the workers. Allowances are usually divided into four classes, namely, personal, fatigue, unavoidable delays, and special.

Personal Allowances.—The first question of allowance to claim the attention of the time-study man is the allowance for personal requirements. The items which come under this class are few in number, and the amount of time used for this purpose varies with the person rather than with the conditions of the work. Thus the amount of time required by the average normal person should be determined and added to the standard time in the form of a constant percentage.

Fatigue Allowances.—The items which are classed as fatigue vary in number and amount according to the working conditions, job conditions, and the length of the operation. The question of fatigue has caused considerable discussion, and there have been various theories and ideas advanced concerning ways of counteracting the effect of fatigue on the worker. Extensive experiments have been conducted to determine the effect that rest periods have on fatigue. Some very interesting results have been obtained from these experiments, but the results and claims are not consistent. This inconsistency is believed to be due to the human element. It is believed that a fair fatigue allowance should be determined and added to each job to be used at the discretion of the operator. Then those whose physical condition is such that they can work more steadily than others will get the benefit of the added effort in the form of increased earnings. This is fair to those who require rest periods as well as to those who do not, for physical capacity is one measure of ability and worth. There are some classes of work for which only the physically strong are fitted, and even the strongest can work only a comparatively small part of the time. The time-study man must determine the particular conditions surrounding each job and make allowances for them accordingly.

Unavoidable Delays.—Unavoidable delays are delays which occur in spite of the efforts of the operator to prevent them. They are delays which are out of the control of the operator and may occur to the good as well as to the poor operator. It is true, of course, that a good operator with greater experience will have fewer delays than a poor operator, but this is because of his better knowledge of conditions, acquired over a number of years, which permit him to plan ahead. The better man will gain in proportion to the amount which he reduces delays, which is but just.

The unavoidable delays which may occur on a given class of work depend on the nature of the work and the conditions surrounding it. Where a machine is set up by a special set-up man, the operator may have to wait for a few minutes until the set-up is completed. If the time is long, he should be allowed to stamp an extra day-work time slip to cover the time spent in waiting. Where it is comparatively short, it will not pay him to make the necessary trips to the office, but he will lose the waiting time just the same. The delay allowance must cover this lost time. It

must also cover such small delays as those caused by an occasional hard or warped casting, the breakage of tools such as drills and taps, time spent on making minor repairs on patterns or core boxes, interruptions by foreman, production man, or engineers, delays at tool room or storerooms, time lost working on castings which are discovered to have blow holes after partial machining where the quantity is not great, and other similar small unavoidable delays.

It is always best to have as nearly ideal conditions as possible, and the time-study man should do all he can to insure this. Often such conditions do not exist, for the work may be of such a variable nature that to maintain conditions which would be considered ideal for all cases would be so expensive as to be prohibitive. In any event, the conditions should be as good as is practicable, the element of expense being taken into account. After the time-study man has determined what conditions should exist and has done what he can to bring them about, he should make a thorough analysis and study to determine every point where a loss of time may occur which would not be the fault of the operator. Thus he will arrive at the correct allowance to make for unavoidable delays.

Special Allowances.—Within a given class of work, there may be certain jobs on which delays or fatigue are much greater than is usually the case. The ordinary allowances for fatigue and delays will not be great enough to cover these jobs. For instance, a blacksmith may have a few jobs on which the flow of work is practically steady and he will have no time between heats to rest. Here fatigue is greater than that covered by the usual allowance, and an additional special allowance must be made.

Again, consider a man winding insulating tape on copper coils. These coils are ordinarily light enough to allow the operator to handle them by himself. Certain large sizes, however, are too large for him to handle alone, and he needs another man to help him. He may experience an unusual delay in waiting for a laborer to come and help him, and a special allowance must be made on these particular large jobs to cover time so lost.

Certain materials require special allowances. A machine operator may have a greater amount of scrap when machining a particularly brittle material than he would ordinarily experience. For example, a milling-machine operator would not expect any scrap due to breaking or cracking of material when milling cast

iron or brass if he were using the proper speeds and feeds. When, however, he is working on an order of soapstone parts, he will have a certain amount of scrap due to the chipping of the edges even though he be using the speed and feed which have been established as best for doing the work. Here a special allowance must be added for milling jobs made out of this material.

These few examples will suffice to show under what general conditions special allowances are required.

Determination of Allowances.—The kind and the amount of allowances to be made should not be estimated nor decided in an arbitrary manner, but should be the result of thorough analysis and careful study. A number of individual workers are studied for a week or two, or even longer, depending on the variableness of the class of work. When the study is being taken, the overall time for each piece is noted as such and all delays are listed in the columns for foreign elements. If the overall time is long, more foreign elements may occur than there is space provided for on the time-study form. When the columns for foreign elements are filled, several columns in the body of the time-study form may be roughly blocked off in pencil and used for noting additional foreign elements. Such time studies should extend continuously over a full working day, and a careful watch should be kept of every move made by the operator.

After the time study has been completed, the delays should be classified as personal, unavoidable, special, and unnecessary. Unnecessary delays or delays which may be purposely introduced by the operator should not be considered when establishing allowances, and the time thus consumed should be subtracted from the length of the working day before computing the other percentages. The time lost due to the other delays should be totaled and the percentage thus lost be computed by dividing time lost by the total length of the working day less time lost through unnecessary delays. After delay percentages have been found from several all-day studies on different operators, the results should be averaged. The percentages thus determined may be established as the allowance percentages for delays within the particular class of work on which the studies were made.

The percentage to be allowed to care for fatigue may be found from these same studies. When the studies are taken, the skill of the operator and the effort exerted during the first part of the day should be noted. When the study is worked up, the overall

productive time for each piece may be found by deducting the time spent on foreign elements while the piece was being made from the overall time for that piece. The standard time for doing this particular operation should be established by a detailed time study. Now, if the operator observed on the all-day study has been properly rated as to skill and effort at the beginning of the day, the net overall times for doing the job at the beginning of the day after being leveled should correspond closely with the standard time established by detailed time study. That is, when a man for whom a leveling factor of 1.10 has been determined is working on a job having a standard time of 0.075 hour, it will be found that his net overall time for each piece at the beginning of the day will range within a few per cent plus or minus of $\frac{0.075}{1.10}$ or 0.0682 hour. Expressing this algebraically,

$$\frac{S}{L} = T,$$

or

$$TL = S,$$

where L = leveling factor.
S = standard time per piece.
T = net overall time per piece.

As the day progresses, the worker will begin to feel the effects of fatigue. His net overall times will start to increase because fatigue is slowing him up. If a detail time study were being taken on him, he would receive a lower effort rating than he did in the morning. If, however, the leveling factor is not changed, the above equation will no longer hold true but will become

$$TL - d = S,$$

where d is the amount of time the man is actually slowed up by fatigue.

The time d lost due to fatigue will be an ever-increasing amount as the day progresses unless rest periods or change of work lessen the effects of fatigue. The total amount of time D thus lost during the day may be found from the sum of net overall times, O and the number of pieces worked N from the equation

$$OL - D = NS,$$

or

$$D = OL - NS.$$

The amount of time lost due to fatigue expressed in per cent may be found from the equation

$$\left(\frac{OL - NS}{NS}\right) 100 = \text{per cent fatigue factor,}$$

or

$$\left(\frac{OL}{NS} - 1\right) 100 = \text{per cent fatigue factor.}$$

To illustrate this, an all-day time study was taken on the operation of making die castings. It was found that the operator spent his time during the day as follows:

		Per Cent
Net overall time	Make castings	70.4
Set-up	Oil die	4.4
Set-up	Fill machine with metal	6.4
Unavoidable	Repair machine, tools, etc	11.3
Personal	Drink, etc	3.5
Set-up	Prepare to start and clean up	4.0

The standard time per piece had been previously established as 0.0098 hour. During an $8\frac{3}{4}$-hour day, the operator made 682 castings. The leveling factor as determined from his morning rating was 1.12. Thus the amount of time lost by this operator due to fatigue was

$$\left(\frac{0.704 \times 8.75 \times 1.12}{682 \times 0.0098} - 1\right) \times 100 = 3.3 \text{ per cent}$$

The average of the fatigue factors thus found from several all-day studies will give a representative fatigue factor to use for that class of work.

CHAPTER XV

ALLOWED TIME

After the time study has been worked up and the elemental standard times determined, and after a proper percentage allowance for existing conditions has been definitely established, it is necessary to determine the actual time value which will be given for doing the job. This time value is called the allowed time. It must include not only the time for performing the repetitive elements of the operation but also it must include the time for doing the non-repetitive or so-called set-up elements. In short, time must be allowed for every necessary operation performed in turning out a complete job on a number of pieces. There are several ways of handling this allowed time, and a brief discussion of the relative merits of each is given in the succeeding paragraphs.

Determination of Set-up Time.—There are certain operations which are not repeated for every piece but which must be performed if the job is to be done. These operations occur at the beginning and ending of a job and are known as the set-up operations.

In determining the set-up time, the time-study man will study all the elements that occur while making the set-up and record the time for doing them. The same care and attention should be exercised in studying a set-up as when studying the operation to follow. This is especially true where the time allowed for the set-up is likely to be a large percentage of the total time allowed on a given job, for then, if the time-study man has been liberal by neglecting to take out foreign operations, the result will be the same as though he had been careless on the entire job and had established values which were too high. On the other hand, if he had been careless by neglecting to consider some of the essentials in the set-up, the result would be the same as though he had established values which were too low on the entire job. The set-up includes such items as getting the job from the foreman or dispatch clerk, getting all information necessary such as drawings

and other specifications, studying the specifications to determine the job requirements and the tools needed, getting the tools from the tool room, and if necessary, properly grinding them, setting and adjusting tools and stops if a machine job, or making the preparatory set-up and adjustments of tools and equipment if a bench job, and making a trial piece or trial layout and having it approved by inspector and foreman. The foregoing operations usually occur at the beginning of a job. Still other operations which are considered as being part of the set-up occur at the ending of a job, for example, removing all special equipment that has been set up for the job just finished, returning this to the tool room, cleaning the machine or work station preparatory to starting the next job, making out a time card, and shipping the job just completed.

After the time for each elemental operation of the above nature, exclusive of all foreign operations, has been carefully determined, the individual times are totaled. The result is established as the set-up time for the operation under consideration and is recorded as such to be allowed each time the job is worked.

Determination of Time for Each Piece.—In the each-piece time should be included the total time necessary for doing all of the necessary repetitive elements of the operation, that is, all of the elements which are repeated each time the operation is performed. This is simply the sum of all of the elemental standard times for every element of one complete cycle of the operation, together with the proper allowances. The elemental standard times were determined from the time study taken on the operation. The percentage allowance was determined for the particular class of work by a series of studies extending over a number of full working days. The elemental allowed times were found by increasing the elemental standard times by the proper per cent allowance. Finally, the allowed time for each piece will be the sum of these elemental allowed times, each element being multiplied by the number of times it occurs in one cycle.

Distribution of Set-up Time over Manufacturing Quantities.—This method of handling allowed time is rather crude and is not very accurate, but it is at least workable. The manufacturing quantity in which the job is likely to be put through the shop is determined by past records or is merely estimated. Then the

time required for set-up operations is divided by the number of pieces in the job lot to determine how much of the set-up time shall be apportioned to each piece. This time is added to the each-piece time, and the result is the allowed time for each piece for doing the operation.

If the job always comes through in the predetermined quantities, this method will give an accurate time value for the job. This is, however, seldom the case. An unforeseen large order will give the worker an advantage, for the set-up time will be distributed over a greater number of pieces. If the job occurs in smaller quantities, the worker will be correspondingly penalized. If a shortage occurs due to defective material or workmanship, the worker may have to make a complete set-up for only one or two pieces. Obviously, in this case, he will fail to meet the allowed time by a large amount. Costs as determined from these allowed times will not be accurate if the manufacturing quantities vary. They will, however, be easy to compute since only one time value must be considered.

In order to overcome the chief objection to this method, that of inaccuracy when the manufacturing quantities vary, sometimes several allowed times are established depending on the number of pieces on order. The allowed time per piece will be a certain amount on lots up to 10 pieces. Between 10 and 20 pieces it will be another value slightly less than the first and so on. The accuracy of this method depends on how finely the divisions are made. In determining the cost of doing the job, the actual cost is more closely approached. The cost system, on the other hand, is more complicated, paper work is greatly increased, and record files are more cumbersome.

The Set-up as a Separate Allowed Time.—Often, the set-up is an entirely separate operation, that is, the set-up is made without actually completing any work, or again, the set-up is made by an entirely different operator from the one who uses the set-up to do the job. The reasons for this latter condition are several. It may be that the class of operator required to make the set-up is high, while the class of operator required to use it is comparatively low. In a case of this kind, it is readily seen that it would be considerably cheaper to have set-up men to take care of the setting up of a group of machines. The same thing is true of work other than machine work. For example, in making large transformers, one of the operations is known as "building."

Preparatory to building, it is necessary to set up the job, which consists of blocking up the base and setting up the frame, coils, and insulation. This work is done by a group of men who are specialists in this line. Thus there are always set-ups ahead of the other lower-grade men who go from one set-up to another to build up the iron laminations. Another advantage derived from having set-up men is continuous performance or elimination of lost time. This is accomplished by having extra machines always set up so that when an operator finishes a job on one machine, he moves over to another machine to do the next job which is already set up. It is, of course, to be understood that the conditions will warrant the investment in the additional machines. In any of the above or similar cases, it is desirable and proper to establish the set-up time as a separate allowance and record it accordingly.

Partial Set-ups.—By a partial set-up is meant a set-up where all set-up operations do not have to be performed, because due to similarity of jobs, part of the set-up already made need not be disturbed. For example, one of the tools used in making a part on a J. & L. turret lathe may be used without adjustment on the next job. As a result, only five tools need to be set up. In such a case, should the set-up man be paid for setting up only five tools or should he be allowed time for setting the entire six?

At first glance, it might seem that the operator should be paid only for what he does. If he needs to set but five of six tools necessary for doing a certain job, he should be paid for setting five. Theoretically, this is as it should be, but there are several other practical considerations involved.

Where set-up time is short and where a large variety of comparatively short orders is worked daily, it is exceedingly hard to give partial set-ups. It is not generally possible to have the foreman or the time-study man check every set-up, and it is generally necessary to rely on the honesty of the set-up man or of the machine operator himself for information regarding set-ups. Men who are absolutely honest with each other outside the shop seem to regard a large company in a different light, and it is often very hard to make them feel that they are doing wrong when they turn in time undetected for something they have not done. It is safe to say that the majority of operators will not be conscientious about reporting partial set-ups. If they do not report them, they will get paid for full set-ups. They know that they

are "putting something over" on the company, and the psychological effect is bad. They are likely to exceed bounds in other directions, if they are given a little leeway in one.

Supervision by responsible persons is generally out of the question, because the additional expense involved is not offset by the savings made.

Another factor that is very important is that when set-ups are controlled, there is no incentive for the operators to plan their work to the best advantage. Since they get paid only for what they do, they do not care whether they make all complete set-ups or not. On the other hand, if they are allowed complete set-ups on all jobs, they will plan so that every minute that it is possible to save on set-ups is saved. Thus production is speeded up.

With the above considerations in mind, it seems best on work where set-ups are short and the time which may be saved small to allow complete set-ups on all jobs. Supervisory expense is reduced, overhead is reduced for this reason and because production is increased, and the psychological effect on the workers is better.

Where set-ups amount to considerable time, it generally takes longer to complete the jobs themselves. It is easier for the supervisors in the department to keep track of the various jobs and note when only partial set-ups are necessary. In this case, it will pay to control set-ups.

Whether or not it will pay to control the set-ups on a given line of work may be determined by the time-study department with the above considerations taken into account.

First-piece and Additional-piece Time.—Under this method, a certain time value is allowed for doing the first piece and another for doing each additional piece. The first-piece time allows time for every operation which would be performed if only one piece were made. It includes the set-up time and the time for performing the repetitive operations for one complete cycle.

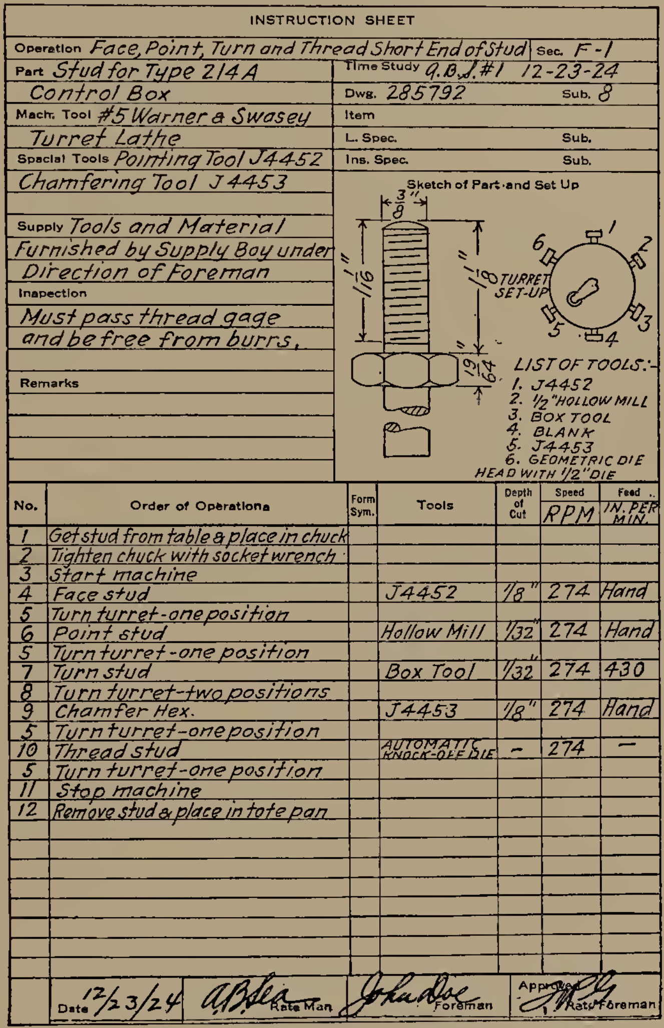
The repetitive operations performed on the first piece will generally not be done in the same time that the same operations are done on succeeding pieces. The operator will not have had a chance to get into the swing of the work, and he will take more time to do the first piece. On machine work, he will have to check and measure the piece more often than he will after he becomes familiar with the correct positions of his stops and dials. In bench work, certain difficulties will appear which the operator

will subsequently overcome when he has become accustomed to the job. In molding, a molder may not prepare his parting exactly right the first time, causing a breakage of a section of sand and later necessitating extra patching. On the following pieces, he will know exactly how to prepare the parting, no breakage will occur, and the total operation will be performed in less time. So it is in practically every line of work, and hence the sum of the set-up and the additional-piece times will not give a true first-piece time. Instead, the first-piece time is computed by adding to the set-up time the additional-piece time increased by a certain percentage to care for the delays experienced on the first piece. The additional-piece time is, of course, the allowed each-piece time as determined by time study.

This method of handling allowed time gives very accurate costs, since the costs will be based on the time actually spent on the job. The job may be billed at actual cost, or as is more common, in order to avoid constantly changing costs, the additional cost of the first piece is absorbed in the overhead expense, and the cost figured on the additional-piece-time value.

Special Allowed Time.—Very often it is necessary to allow extra time for conditions which were not considered in establishing the standard allowance. A large lot of extra-hard castings may be encountered which will necessitate a lower machine feed and a smaller cutting speed than that which has been established, or an order of castings may be out of shape due to poor molding or warping, causing a loss of time in chucking and handling. Again, a job may be wanted in a hurry and the material out of which the job is to be made is out of stock, thus making it necessary to substitute some other material which will answer the purpose, but which may be harder to machine if a machine job, or harder to file, saw, or bend if a bench job. Extra time must be allowed to take care of such conditions. The amount of extra time should be determined by time study and added to the standard allowance, and given as a special allowed time for that particular order only. Other examples where special allowed times are necessary are where work is performed on a machine which is in need of repair, where proper tools are not available, where existing conditions are not right for a special job, where work is in a state of development, or where a temporary change in design has been made. The examples here given will suffice to show when a special allowed time is warranted. The above

conditions may also be taken care of by having the work done on the straight day-work basis, but it will usually be found more satisfactory to the worker and more economical to the employer to make a special allowance wherever the extra time can be intelligently determined.


INSTRUCTION SHEET

Operation Face, Point, Turn and Thread Short End of Stud	Sec. F-1
Part Stud for Type 214A	Time Study Q.B.J.#1 12-23-24
Control Box	Dwg. 285792 Sub. 8
Mach. Tool #5 Warner & Swasey	Item
Turret Lathe	L. Spec. Sub.
Special Tools Pointing Tool J4452	Ins. Spec. Sub.
Chamfering Tool J4453	Sketch of Part and Set Up
Supply Tools and Material	
Furnished by Supply Boy under	
Direction of Foreman	
Inspection	
Must pass thread gage	
and be free from burrs.	
Remarks	

No.	Order of Operations	Form Sym.	Tools	Depth of Cut	Speed RPM	Feed IN. PER MIN.
1	Get stud from table & place in chuck					
2	Tighten chuck with socket wrench					
3	Start machine					
4	Face stud		J4452	1/8"	274	Hand
5	Turn turret-one position					
6	Point stud		Hollow Mill	1/32"	274	Hand
5	Turn turret-one position					
7	Turn stud		Box Tool	1/32"	274	430
8	Turn turret-two positions					
9	Chamfer Hex.		J4453	1/8"	274	Hand
5	Turn turret-one position					
10	Thread stud		AUTOMATIC KNOCK-OFF DIE	–	274	—
5	Turn turret-one position					
11	Stop machine					
12	Remove stud & place in tote pan					

Date 12/23/24 — Rate Man — Foreman — Approved Rate Foreman

FIG. 34.—Instruction sheet for job on which model time study was made.

Individual conditions will determine which of these systems may be applied most advantageously. A shop manufacturing a standard product might use the method of distributing set-up time over manufacturing quantities most conveniently, while the job shop would find the method of first-piece and additional-piece time best suited to its conditions. The point to be

borne in mind is that the time spent on set-up operations must be allowed for when establishing a time value for doing a job. The allowed time, regardless of the method used, must be the standard time for performing the complete operation together with all time allowances for fatigue, delays, and the like.

Instruction Sheet.—When an operation has been thoroughly studied and the best method for doing it has been determined, this method should always be used. The operator may be taught the proper method by the foreman or by a special instructor, or he may be guided by an instruction sheet. An instruction sheet for the operation covered by the model time study is shown in Fig. 34. It gives the detail operations in the order in which they should be performed, and it tells what feeds and speeds to use.

Instruction by the foreman or an instructor is not so exact and consistent as the other method, but it is more practicable. Making instruction sheets and keeping them up to date involves a tremendous amount of clerical work where the nature of the work is at all varied. In plants making a standard product or in processing industries where methods are not changed frequently, instruction sheets are easier to keep up. The very fact, however, that changes are not made frequently enables the operators to learn all of the details of their work by heart, thus defeating the purpose of the instruction sheet.

CHAPTER XVI

STUDYING EXISTING CONDITIONS

The advantages of having working conditions as nearly ideal as possible before making time studies have been fully discussed, but it must not be concluded that poor working conditions, obsolete or inadequate equipment and out-of-date methods are sufficient to prohibit satisfactory results from time-study work. It must be remembered that time study is industry's tool and even though it is sometimes impossible to apply it to the maximum advantage, it will, nevertheless, pay for itself many times over wherever it is introduced for the first time, provided it is in the hands of those who understand it and know how to use it. The last-named provision is especially necessary, for scientific time study has suffered greatly at the hands of novices and self-styled experts. It is just as wrong to put time study into the hands of untrained and incompetent clerks as it is to put a high-grade scientific instrument into the hands of an ordinary laborer and expect good results. In fact, the harm that can result in the first case may be much greater than any that could possibly result in the second. The damage that the laborer can do is probably limited to the value of the instrument and can be measured in dollars and cents, but wrongly applied time study may result not only in a direct and measurable financial loss but also in a detrimental effect upon the morale of the working force and upon the confidence of the management. It is in those places where time study has never been tried that the confidence and support of the management must be secured and maintained. Time study must pay its own way and also leave a comfortable margin of profit in order to justify its existence. In the beginning, then, it is sometimes necessary to show results quickly and not call for large financial outlays for improved equipment or rearrangement of working facilities. If the management is somewhat skeptical of the benefits from the beginning, it is not good policy to increase existing doubts by

insisting upon expensive changes, nor is it necessary. In fact, it is in the initial stages of time-study work that the greatest savings can be effected for the money expended. As greater refinements are introduced and manufacturing methods become more highly organized, the effect of the Law of Diminishing Returns becomes evident, for the increased savings are no longer proportional to the increased cost of maintaining time-study work. It still pays but it does not pay so high a return on the investment as it did at the beginning. There is a theoretical saturation point beyond which further refinements in time-study work are no longer profitable, although it is doubtful if this point has ever been reached as a practical matter on account of the ever-changing conditions in industry. It is, therefore, often necessary to study conditions almost as the time-study man finds them and then by further study revise the original time values as improvements are made by the management.

Wherever labor can be measured and, thanks to time study, it is indeed a rare case that cannot be measured, that labor can be placed on an incentive method of wage payment. There are a number of meritorious systems of wage payment, all of which are based on time study. The primary intent of this book is to explain the methods and uses of time study and not to champion any particular system of wage payment. It is understood, of course, that the economic value of time study can be realized only through the medium of a good incentive system of wage payment. On the other hand, no system of wage payment can long survive that is not founded upon an accurate method for measuring human effort. Analytical time study is the most practicable and feasible means to this end that has so far been developed. Thus it will be seen that the wage-payment system and time study upon which the former is constructed go hand in hand, and the success of each depends to a large extent upon the worthiness of the other. The mistake is sometimes made of overlooking the influence of good time-study work and giving to the wage-payment system too large a share of the credit for savings. The best-known wage-payment system would quickly fall into ill repute if established time values were incorrect and inconsistent. Hence, it is highly desirable to ascertain, when inaugurating time-study work in a plant, first, that it be done by those who thoroughly understand their business, and second, that a good wage-payment system be used in applying it. Incident-

ally; a number of the leading wage-payment systems and their applications are briefly discussed in Chap. XXXVII.

Time study has been referred to as a tool. The analogy may be carried further by comparing it specifically to a machine tool, an engine lathe, for instance. The primary function of an engine lathe is to remove metal from raw stock until the piece is brought down to the desired dimensions. This is not done, however, in one operation. First, there are one or more roughing cuts with heavy feeds that take off the outer scale and irregularities and more closely approach the finish dimensions, say to within $\frac{1}{16}$ inch. Then, perhaps there is a semifinishing cut with a fine feed that brings the dimensions to within $\frac{1}{64}$ inch, and finally the finishing cut. If still greater accuracy is desired, the job will probably be transferred to a grinder. The raw casting may be compared with the plant in which no time-study work or incentive systems have ever been tried. Like the lathe operator who takes the casting as it comes from the foundry and proceeds to set up his machine for the roughing cut, so does the trained time-study man go into the plant and study things just as he finds them. The first roughing cut removes considerable of the excess metal, perhaps over half of it. In like manner can the time-study man establish time values and apply an incentive system of wage payment that will, on the first attempt, with practically no improvement in equipment or conditions, effect an enormous saving in labor costs, perhaps as much as half of the total saving that will ever be possible even after all justifiable improvements have been made. To secure the additional possible saving will doubtless require more than a proportionate increase in effort and expense just as it cost more to remove the second half of the excess metal on the lathe operation; yet the work should be carried on because the theoretical saturation point previously referred to has not been nearly attained. Innumerable examples could be quoted of the enormous savings that have been effected by the initial application of time-study methods and the placing of day-work operations on an incentive system of wage payment. It will suffice for present purposes to give but a few typical examples covering a wide variety of jobs.

Making Reinforced-concrete Slabs.—The product on this job was a flat slab of reinforced concrete about 5 feet long by 2 feet wide by 2 inches thick, to be used for roofing factory buildings. The concrete was mixed and poured into flat molds using

cut-steel mesh for reinforcing. A group of laborers were doing the work for a flat hourly rate corresponding to the prevailing rates for that class of work. Before any time studies were made, the production was around 80 slabs daily. Only a short time (1 week) was required to get the necessary time studies and the job was put on an appropriate incentive wage-payment basis. Practically no changes were made in the manner of doing the work and in the equipment used; yet within the amazingly short time of 2 weeks after the incentive wage system was started, production increased to 425 slabs per day with the same crew of men. Each man's earnings were nearly doubled but this was more than justified by over a 400 per cent increase in production, and more than a 62 per cent decrease in unit labor cost.

Cleaning Castings in Alloy Foundry.—The work of cleaning castings covered such things as knocking out core sand, sand blasting, cutting off sprues, gates, and risers, grinding off fins and other rough surfaces, washing when required, and chipping and filing when necessary. The work was very disagreeable and undesirable, and labor turnover was very high. It was extremely difficult to keep men on the job when labor was scarce. Before the work was analyzed and studied, a crew of 78 men was necessary to keep up with foundry production, which normally was around 600,000 pounds of finished castings per month. In this case some changes were at first recommended by the time-study man, but the management was reluctant to carry out the recommendations and the work was studied without the changes being made. Two months after the time studies were completed and the incentive system started, the work that had required a gang of 78 men was being done by 32 men. Individual earnings were increased 35 per cent but against that was an increase in individual production of 144 per cent and a reduction in the force of 59 per cent. The actual saving in labor cost was equivalent to 35 men or about 45 per cent.

Removing Excess Gum Tape from Armature Coils.—This was another disagreeable job on which the labor problem was always acute. It was somewhat isolated from the other work in the department which made close supervision impossible, and the laborers employed doubtlessly took advantage of this situation. The five men on the job were sometimes unable to keep up with the flow of work. Time study and an incentive system brought about the almost unbelievable results of eliminating four of these

five men. The one man who continued to do the work increased his earnings about 67 per cent, but the net saving in labor cost was also about 67 per cent, and individual production was increased 400 per cent.

Storeroom Work.—A group of 14 men were employed in a storeroom. Their work consisted of receiving, storing, and supplying material to workmen in a large manufacturing department. In busy times there was an average of about 90 man-hours a week of overtime at time and one half, which would have been equivalent to 3 extra men or making an equivalent of a group of 17 men working regular hours. These men were not particularly interested in the production on the manufacturing floor. It was necessary for workmen to go to the storeroom frequently for material, and in general the service was poor. The incentive system that was established after sufficient time studies had been made provided that the earnings of the storeroom attendants should be determined by the volume of finished work produced by the department. This definitely tied the storeroom to the production activities, and the attendants were definitely increasing their own earnings when they helped the producers on the floor to a greater output. The original force equivalent to 17 men in busy times was reduced to 9 men with an average increase in individual earnings of 25 per cent.

Crating Finished Product for Shipment.—Ten rough carpenters were regularly employed on a straight hourly basis on this particular job, which was attended with the usual difficulties of a day-work job where steady flow is required. The work consisted of taking the piece of apparatus from an industrial car as it came from the manufacturing floor, placing it in the crate which had been previously placed on a roller conveyor, blocking the machine inside the crate, nailing on the lid, marking, and stacking preparatory to shipment. After the job was studied and placed on an incentive system of wage payment by a competent time-study man, the number of men in the group was gradually reduced from the original 10 until only 2 of the best men remained. The day-work rate had originally been about 53 cents an hour making a total labor cost of $5.30 an hour. Under the new incentive plan each man earned $1.10 an hour making a total hourly labor cost of $2.20. This was an increase in individual earnings of about 108 per cent, but to offset this their individual production had increased 400 per cent, the total force had been reduced

80 per cent, and a saving of over 58 per cent in labor costs had been effected.

Band-saw Operation.—Three band saws were employed exclusively on sawing asbestos lumber. Three men were employed on day turn and three on night turn, making six men in all working the equivalent of regular day-turn hours. They were paid 53 cents an hour on a day-work basis. Time studies were made and the work was put on an incentive basis of wage payment. Some minor changes, such as changing the speed of the saws, were recommended by the time-study man and adopted, but none of them involved additional expense or delay. Within 3 months two men were doing the work formerly done by the six. The new earnings were 90 cents an hour, an increase of 70 per cent, but individual production was increased 200 per cent and the cost was reduced over 43 per cent.

Summary of Examples.—In selecting the foregoing examples of quick results from time-study work, it was not only the intent to show what enormous savings are sometimes possible, but also to show the practically unlimited application of time study by taking examples that represent greatly diversified lines of work. The results of these examples are briefly summarized below:

	Increase in production per man, per cent	Reduction in force, per cent	Increase in individual earnings, per cent	Saving in labor cost, per cent
Making concrete slabs.....	400	0	100	62
Cleaning castings.........	144	59	35	45
Removing gum tape.......	400	80	67	67
Storeroom.................	88	47	25	34
Crating...................	400	80	108	58
Band saws...............	200	67	70	43

CHAPTER XVII

USING THE TIME STUDY

Preceding chapters have been devoted almost exclusively to explanations and discussions of how reliable time studies are made, and now one might well ask, "How are they used?" or "Of what value are the results?" These questions cannot be fully answered in one brief sentence, but much of the answer is contained in the statement that they make it possible to measure human effort in an equitable and consistent manner. Chief among the numerous advantages of being able to measure human effort accurately are those that accrue from using the results as foundations for incentive methods of wage payment. The employer can purchase labor on the basis of the work accomplished and the employee can sell it for what it is actually worth—he gets paid for what he does. Some of the other applications of time-study results are in the laying out of production schedules, the calculation of past and the prediction of future costs and the determination of equipment capacities when planning for increased production. Regardless of the ways in which time-study results are ultimately used, the methods of making the studies and of determining those results are not materially affected. It is the intent and purpose of this book to show how time studies should be made and not to attempt to limit their application which is actually very wide, although it might appear at times that the authors are thinking only of their application to wage payment. It is in this connection that they have been used most extensively, and naturally there is a more prolific supply of examples in this field. Hence, the attention of the reader has been and will continue to be directed to this particular application.

Wage Payment.—From the wage-payment viewpoint, it is necessary, of course, to have a good wage-payment plan in order to realize fully the economic value of time study. Every good wage-payment plan provides that earnings will be determined by the amount of useful work accomplished. In some systems, compensation is directly proportional to output; if output is

doubled, earnings are doubled. The straight piece-work plan is a good example of this type. Other plans provide that earnings increase with increased output but not in the same proportion, on the theory that increased output does not necessarily demand a proportional increase in effort.

Another way in which wage-payment plans differ is in the terms used to express job allowances. The two chief ways of expressing allowances are directly in terms of money and in terms of so many units of time. Referring again to the straight piece-work system, one finds there the best example of using money directly as the allowance for each unit of output. For every unit completed, the worker is paid a definite amount of money, and the computation of his total earnings over a definite time is a very simple matter. The number of units completed is merely multiplied by the amount of money allowed for each. In the majority of approved systems, however, the unit allowance is expressed as so much time, and by various methods of calculation involving the total of the time allowance and a monetary rate, the earnings are calculated.

In any ease and regardless of the wage-payment plan being used, the fundamental method for determining unit allowances is time study. The allowed time as determined by time study may be used without alteration, or it may be converted into other terms according to the wage-payment plan in use, but it must be remembered that time study is the foundation of the entire structure.

Individual Job Values.—Many time studies are made with no other object than to establish a time value for the one particular job under consideration, and with this done, there is apparently no other immediate use for it. It is accordingly filed away against the time when some future use for it might develop.

Time-study Reference File.—This file should be maintained so that the individual time studies may be readily found for reference purposes. There are various methods of filing time studies, depending upon local plant conditions and subdivisions of manufacturing operations. In one case, it may be best to file studies by the departments in which the work was performed; in other cases, classification according to classes of work or types of machine tool equipment may be best.

This file will be comprised largely of miscellaneous studies on various lines of work on which sufficient studies have not been

made to make possible the construction of a formula, because of the low activity of the work or because of an insufficient number of trained time-study men in the organization to do more than take care of immediate pressing demands. Some of the individual studies will probably be independent of and have no relation to the others, having been made with no other object than to determine a time allowance for one particular job. To make a time study with this single purpose in view may be justifiable, and it may even be justifiable to do it again and again, but if there are frequent repetitions on similar jobs that fall in the same general class of work, the uses of the data secured from representative studies may be extended to cover the entire class of work. This may be done by compiling standard data or by constructing formulas by which the time value may be readily determined for any job in the class, without the necessity of actually making a separate time study.

Standard Data.—A compilation of standard data is merely a list of all the different elements that have occurred in all the time studies made on a given class of work and the corresponding time values for each. Every element that differs even slightly from every other element has its own time value. When a job comes up on which no time value has been previously established, the standard data are referred to and a time value selected for each of the elements of the job. It is generally necessary to go on the floor and make an analytical motion study in order to determine the elements that are required for the operation. It may be found that some of the elements of the jobs are not included in the standard data because they had not previously occurred in any of the studies from which the list was made. In this case, those elements should be studied and included with their time values in the standard data.

The standard-data method is frequently used to advantage on machining operations where a considerable part of the time for the operation is cutting time which can be calculated from the speed, feed, and depth of cut. A list is generally made up for each type of machine tool, and this list includes values for the various motions necessary for the manipulation and operation of each particular machine. In other words, a study is made of the machine rather than the work. The merit in this plan is readily seen when one considers that the piece upon which the work is being done will have little, if any, influence on the time required

to manipulate the different parts of the machine, because they have a definite mechanical relation to each other. For example, such elements as "start machine," "stop machine," "release

Sheet 1

STANDARD DATA—AVEY SENSITIVE DRILL PRESS

Procedure for Using Avey Sensitive Drill Press Data

1. Take a careful motion study of the proper sequence of operations.
2. Pick out the proper time for each operation from sheet 3 or 4.
3. Measure the distance of metal to be drilled and add the length of the drill lead (as specified in table on Sheet 1 or 2) and multiply that sum by the proper time to drill 1 inch as shown in table on Sheet 1 or 2.
4. The total sum of all the values selected will be the time allowed to perform the operation on each piece.
5. Time values for tapping operations are found by using the formula shown on Sheet 2.
6. Time values for setting up the machine are shown on Sheet 5.

TABLE OF DRILLING VALUES

Time to Drill 1 Inch with Hand Feed

Drill diameter in inches	Length of lead in inches	Brass		Cast iron		Medium steel	
		Speed. Revolutions per minute	Time in hours	Speed. Revolutions per minute	Time in hours	Speed. Revolutions per minute	Time in hours
Carbon-steel drills							
$\frac{1}{8}$	0.037	4,750	0.00102	1,240	0.00425	1,020	0.00680
$\frac{9}{64}$	0.042	4,250	0.00110	1,060	0.00450	900	0.00740
$\frac{5}{32}$	0.047	3,850	0.00118	920	0.00475	820	0.00780
$\frac{11}{64}$	0.051	3,500	0.00124	850	0.00500	740	0.00820
$\frac{3}{16}$	0.056	3,250	0.00130	830	0.00515	680	0.00860
$\frac{13}{64}$	0.061	3,000	0.00136	830	0.00530	640	0.00890
High-speed steel drills							
$\frac{7}{32}$	0.065	2,750	0.00140	1,360	0.00270	1,010	0.00600
$\frac{15}{64}$	0.070	2,550	0.00145	1,300	0.00275	960	0.00610
$\frac{1}{4}$	0.075	2,400	0.00148	1,240	0.00280	910	0.00620
$\frac{17}{64}$	0.080	2,200	0.00151	1,170	0.00285	870	0.00630
$\frac{9}{32}$	0.084	2,050	0.00155	1,120	0.00290	830	0.00640
$\frac{19}{64}$	0.089	1,950	0.00160	1,070	0.00295	790	0.00650
$\frac{5}{16}$	0.094	1,800	0.00162	1,020	0.00300	750	0.00660

FIG. 35a.—Standard data for Avey sensitive drill press.

power feed," "remove tool," and "adjust stops" should require the same amount of time regardless of differences in pieces being worked upon. The work that can be done on a particular machine tool is limited by the physical characteristics and dimensions of

Sheet 2

TABLE OF DRILLING VALUES

Time to Drill 1 Inch with Hand Feed

Drill diameter in inches	Length of lead in inches	Brass		Cast iron		Medium steel	
		Speed Revolutions per minute	Time in hours	Speed Revolutions per minute	Time in hours	Speed Revolutions per minute	Time in hours
High-speed Steel Drills							
21/64	0.098	1,700	0.00164	975	0.00305	730	0.00670
11/32	0.103	1,600	0.00165	930	0.00310	700	0.00680
23/64	0.108	1,550	0.00168	885	0.00315	670	0.00690
3/8	0.113	1,500	0.00170	845	0.00320	640	0.00710
25/64	0.117	1,450	0.00172	805	0.00325	610	0.00720
13/32	0.122	1,375	0.00175	770	0.00330	590	0.00730
27/64	0.127	1,325	0.00177	740	0.00335	565	0.00740
7/16	0.131	1,275	0.00179	710	0.00340	540	0.00750
29/64	0.136	1,225	0.00181	680	0.00345	520	0.00760
15/32	0.141	1,175	0.00183	660	0.00350	500	0.00770
31/64	0.145	1,150	0.00183	635	0.00355	480	0.00780
1/2	0.150	1,125	0.00187	615	0.00360	460	0.00790
33/64	0.155	1,075	0.00189	595	0.00360	440	0.00800
17/32	0.159	1,050	0.00191	575	0.00365	430	0.00810
35/64	0.164	1,025	0.00193	555	0.00370	420	0.00820
9/16	0.160	1,000	0.00195	540	0.00375	410	0.00830
37/64	0.173	975	0.00197	520	0.00380	400	0.00840
19/32	0.178	950	0.00201	505	0.00385	390	0.00860
39/64	0.183	950	0.00203	485	0.00390	380	0.00870
5/8	0.188	925	0.00204	475	0.00395	370	0.00880
41/64	0.192	900	0.00206	460	0.00400	365	0.00890
21/32	0.197	875	0.00208	450	0.00405	355	0.00900
43/64	0.202	850	0.00210	440	0.00410	345	0.00910
11/16	0.206	825	0.00212	435	0.00415	340	0.00920
45/64	0.211	800	0.00214	430	0.00420	330	0.00930
23/32	0.216	800	0.00216	425	0.00425	320	0.00940
47/64	0.221	775	0.00218	420	0.00430	310	0.00950
3/4	0.225	750	0.00220	420	0.00430	300	0.00960

Formula for Tapping Values

P = pitch of thread
L = distance tapped
S = speed of tap in revolutions per minute

Brass

$$\text{Time} = \frac{0.0584\,PL}{S}$$

4–40 to 20–18 = 1,250 r.p.m.
3/8–16 to 5/16–32 = 950 r.p.m.

Medium Steel

$$\text{Time} = \frac{0.0743\,PL}{S}$$

4–40 to 8–32 = 500 r.p.m.
12–24 to 20–18 = 900 r.p.m.
3/8–16 to –18 = 275 r.p.m.
5/16–32 = 500 r.p.m.

Cast Iron

$$\text{Time} = \frac{0.0637\,PL}{S}$$

4–40 to 20–18 = 900 r.p.m.
3/8–16 to 5/16–32 = 500 r.p.m.
5/8–20 to 9/16–24 = 450 r.p.m.

FIG. 35*b*.—Standard data for Avey sensitive drill press.

the machine. Hence, it is logical that the machine itself should be made the basis of study on work of this kind rather than the piece or part being made. Figures 35*a* to 35*e* inclusive illustrate the form in which standard data are compiled. This particular set of standard data was compiled for setting time values on drilling done on No. 2 Avey sensitive drill presses.

Sheet 3

AVEY SENSITIVE DRILL PRESS STANDARD OPERATIONS

Part Handling

		Hours
1.	Set small part in jig	0.0013
2.	Set medium part in jig	0.0018
3.	Set large part in jig	0.0021
4.	Tighten screw or locater (per screw) by hand	0.0021
5.	Tighten screw or locater (per screw) spanner wrench	0.0040
6.	Tighten thumb nut (per thumb nut) by hand	0.0008
7.	Tighten Hex nut (per nut) use open-end wrench	0.0018
8.	Close eover (all sizes)	0.0003
9.	Put on cover	0.0020
10.	Put on clamp (per clamp)	0.0010
11.	Release thumb nut (per thumb nut) by hand	0.0004
12.	Release Hex nut (per nut) use open-end wrench	0.0016
13.	Open cover	0.0003
14.	Remove small and medium parts from jig	0.0009
15.	Remove large parts from jig	0.0014
16.	Remove clamp (per clamp)	0.0019
17.	Place small or medium part on drill table	0.0006
18.	Place large part on drill table	0.0009
19.	Remove small or medium part from drill table	0.0006
20.	Remove large part from drill table	0.0012
21.	Move small jig or part to first spindle	0.0005
22.	Move medium jig or part to first spindle	0.0012
23.	Move large jig or part to first spindle	0.0016
24.	Move small jig or part from spindle to spindle	0.0005
25.	Move medium jig or part from spindle to spindle	0.0012
26.	Move large jig or part from spindle to spindle	0.0016
27.	Move small jig or part from hole to hole	0.0004
28.	Move medium jig or part from hole to hole	0.0008
29.	Move large jig or part from hole to hole	0.0010
30.	Get small part	0.0006
31.	Get medium part	0.0007
32.	Get large part	0.0010
33.	Place small part in vise and tighten	0.0024
34.	Place medium part in vise and tighten	0.0024
35.	Place large part in vise and tighten	0.0024
36.	Release vise	0.0009
37.	Remove and lay aside small part	0.0015
38.	Remove and lay aside medium part	0.0017
39.	Remove and lay aside large part	0.0017
40.	Blow cuttings from small or medium jig (air hose)	0.0014
41.	Blow cuttings from large jig (air hose)	0.0020
42.	Clean jig (turn over)	0.0014
43.	Clean jig with brush	0.0018
44.	Insert or remove bushing	0.0005

FIG. 35*c*.—Standard data for Avey sensitive drill press.

It includes, besides time values for all elements which will be performed in making set-ups and in drilling cast-iron, steel, and brass parts, tables of drilling and tapping time values. Thus it is possible to establish time values by merely noting what elements must be performed and by determining the number, size, and depth of holes drilled.

Sheet 4

AVEY SENSITIVE DRILL PRESS STANDARD OPERATIONS

		Hours
	Drill from Layout	
45.	Move small part from hole to hole	0.0006
46.	Move medium part from hole to hole	0.0010
47.	Move large part from hole to hole	0.0012
48.	Move small part from spindle to spindle	0.0007
49.	Move medium part from spindle to spindle	0.0014
50.	Move large part from spindle to spindle	0.0016
	Redrill, Countersink, or Burr	
51.	Move to spindle	0.0005
52.	Move from hole to hole	0.0004
53.	Move from spindle to spindle	0.0005
	Machine Handling	
1.	Raise or lower spindle	0.0003
	Machining	
1.	Drill (see chart)	
2.	Tap (see chart)	
3.	Redrill fiber (per inch)	0.0010
4.	Countersink metal (light)	0.0001
5.	Countersink fiber (light)	0.0001
6.	Countersink metal (deep)	0.0002
7.	Countersink fiber (deep)	0.0002

FIG. 35*d*.—Standard data for Avey sensitive drill press.

Sheet 5

AVEY SENSITIVE DRILL PRESS SET-UP VALUES

		Hours
A.	Set jig or vise on table	0.0061
B.	Check drawing	0.0220
C.	Place tool or chuck in spindle	0.0012
D.	Place tool in chuck	0.0042
E.	Remove tool or chuck from spindle	0.0026
F.	Remove tool from chuck	0.0050
G.	Place tapper in spindle	0.0029
H.	Place tapper collar on spindle	0.0036
I.	Tighten tapper collar	0.0066
J.	Loosen tapper collar	0.0068
K.	Remove tapper from spindle	0.0020
L.	Place tap in tapper	0.0147
M.	Remove tap from tapper	0.0029
N.	Set table to proper height	0.0115
O.	Place speed-reducing pulley on spindle	0.0184
P.	Remove speed-reducing pulley from spindle	0.0086
Q.	Set spindle support	0.0050
R.	Set spindle stop	0.0091
S.	Clean table	0.0204
T.	Sort out tool (each)	0.0113

Total time allowed for first piece =
(values selected from above table) + (time allowed for each piece).

FIG. 35*e*.—Standard data for Avey sensitive drill press.

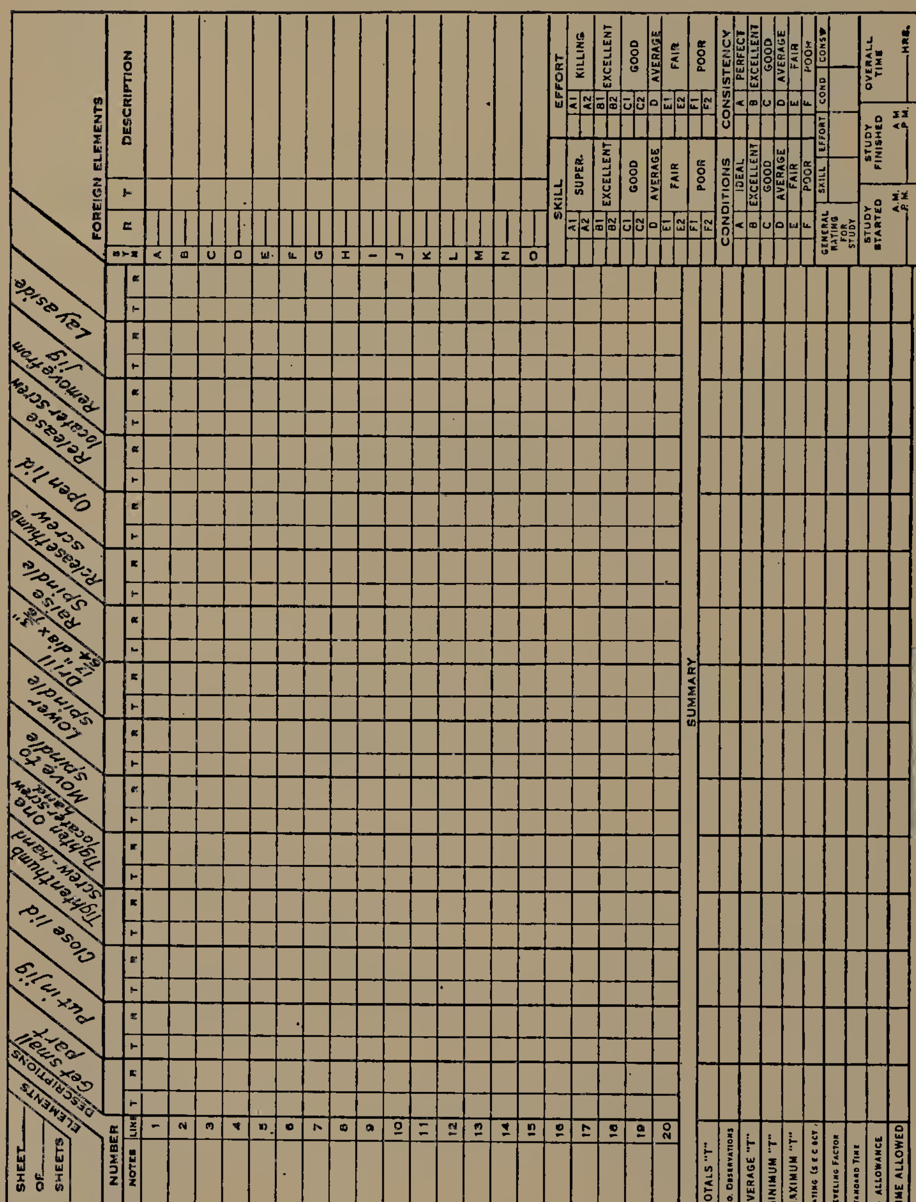


FIG. 36.—Motion study of drilling operation.

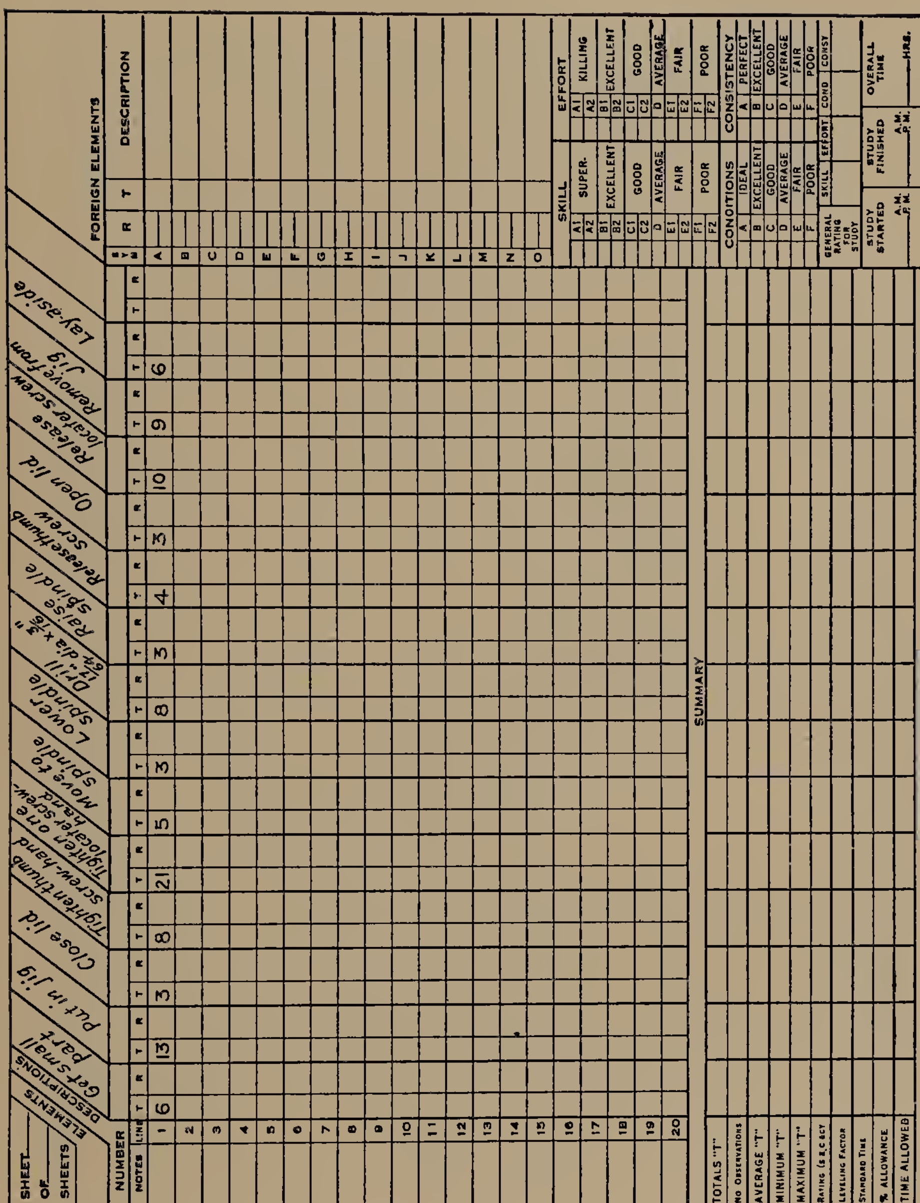


FIG. 37.—Motion study of drilling operation with appropriate time values filled in from standard data.

TIME STUDY SHEET

OPERATION: Drill $\frac{17}{64}$" dia × $\frac{3}{16}$" deep Hole

STUDY No. ______ DATE May 16, 1925

PART DESCRIPTION: Magnet Bracket

MATERIAL: Cast Iron

DEPARTMENT: F-1

OPERATOR: MAN / WOMAN | NAME | No

IDENTIFICATION NUMBERS (DWG. PATTERN. DIE. MOULD. STYLE. ETC.): Dwg 124210 Item 1 or 2

EQUIPMENT: #2 Avey Sensitive Drill Press

MACHINE TOOL No.

SPECIAL TOOLS, JIGS, FIXTURES, ETC.: Jig #24866 C-3

CONDITIONS

OBSERVER: J.B.C.

APPROVED BY

SKETCH

ELEMENTS No.	DESCRIPTION	SMALL TOOL NOS. FEED. SPEED. DEPTH OF CUT, ETC.	ELEMENTAL TIME ALLOWED (BOTTOM LINE OTHER SIDE)	OCCURRENCES PER PIECE OR CYCLE	TOTAL TIME ALLOWED PER ELEMENT
	Set jig on table				0061
	Check drawing				0220
	Place chuck in spindle				0012
	Place tool in chuck				0042
	Remove chuck from spindle				0026
	Remove tool from chuck				0050
	Set table to proper height				0115
	Clean table				0204
	Sort out tool				0113

REMARKS: Drilling Time = .00285(.1875+.080) = .000762 = .0008 ALLOWED TIME 0843

First Piece Time = .0843 + .0102 = .0945 = .095

Add'l Piece Time = .0102 = .010

FIG. 38.—Back of time study sheet showing information which must be recorded when establishing a time value from standard data.

Figure 36 shows how a motion study is taken on the operation of drilling a hole $\frac{17}{64}$ inch in diameter $\frac{3}{16}$ inch deep in a cast-iron bracket held in a jig. Every elemental operation performed is recorded while actually watching the work being done. The time-study man may then fill in the standard allowed time for each element from the value given in his standard data as shown in Fig. 37. Since drilling time per inch is given by the drilling table, he is able to compute drilling time for any depth of hole by multiplying the table value by the depth drilled plus the lead for the proper size of drill.

The back of the time-study form is then filled out as shown in Fig. 38. A list of the elements allowed for the set-up together with the corresponding time values should be here shown. The computations for arriving at the allowed drilling time and the final established time value should also be given. Aside from this, only enough information clearly to identify the job need be recorded. After the time value has been established, the time-study sheet should be filed away so that it will be available for reference if at any future time the established value is questioned.

The Formula.—The method in which time-study data are most profitably employed is in the construction of formulas for setting time values. A comparatively small number of good representative time studies is sufficient material with which to make a formula that will apply to the entire class of work. The obvious advantages of using time study data in this way are that considerable time is saved in establishing time values by formula rather than by individual time study, that the values are more likely to be consistent, that they can be determined from working drawings and other manufacturing information without the necessity of actually observing the operation being performed, and that a high-grade analytical time-study man is not required to apply the formula even though he might have been required to make it.

PART II

FORMULAS

CHAPTER XVIII

PRINCIPLES OF FORMULA CONSTRUCTION

In the first part of this book, the formula has been mentioned several times when bringing out reasons for certain details of the procedure for making time studies. Just what was meant may have been somewhat vague to those who are unfamiliar with the application of formulas to the work of establishing time allowances. It is the purpose of this chapter, therefore, to give a general idea of what formulas used in this connection are before passing on to a detailed account of how they are compiled.

Formulas and Their Application to Time-study Work.—A formula may be defined as the expression of a general fact, rule, or principle by algebraic symbols. It is a convenient way of expressing the manner of variation between two or more interdependent variables. When all but one of the variable quantities are known for a given set of conditions, it is quite easy to find the unknown quantity by substitution in and solution of an algebraic formula. It must be remembered that the formula is only a convenient way of expressing a rule and is not the rule itself. In using formulas in general, there is a tendency to substitute and solve blindly, without first examining the rule expressed by the formula and ascertaining whether or not it is applicable to the case under consideration.

The algebraic formula was probably first confined to the field of mathematics. Its convenience and conciseness were readily apparent, and it was naturally extended to physics, mechanics, electricity, and all branches of applied science. Today the formula is used for expressing such general principles as the laws of economics where actual substitution is never made but where the general relationship of several interdependent quantities is shown.

When time study was first introduced into industry, a separate study was taken on each job as it came along. This required

considerable time and effort and led to the feeling that time study could be applied only to standard lines of work where quantities were large and operations few. It is readily conceivable that the taking and working up of time studies on work of a varied nature might require nearly as many time-study men as operators.

It is by no means necessary, however, to time study every job that comes through the shop. Time-study men were quick to recognize that certain elemental operations in a given class of work were constant regardless of the nature of the piece upon which work was being done. Other elemental operations varied with certain characteristics of the work.

The recognition of these facts led to the compilation of standard data, a sample of which has already been shown in Chap. XVII. It then became apparent that certain operations were performed on every piece worked, that others were performed when the piece had certain characteristics, and that the time for doing still other operations varied in a definite manner with certain variable characteristics such as length, area, or volume. The next step, that of resolving standard data into algebraic formulas, followed as a matter of course.

Advantages of Formulas.—The great amount of time which the use of formulas will save the time-study man is readily apparent. The time required to take and work up a time study on repetitive work will be from 1 to 4 hours where the length of the operation cycle is fairly small, and may be much longer on larger work where one operation cycle may run as high as 100 hours. The time required to set a time value from a formula will, in the majority of cases, range from 1 to 15 minutes, depending on the complexity of the formula and the amount of time required to determine the characteristics of the job. Where all necessary information may be obtained from the drawing of the part, the time value may generally be computed in less than 5 minutes.

With so much time saved in the work of the time-study department, it is obvious that formulas will enable fewer men to cover a given amount of work or the same number of men to handle a much larger territory. The caliber of men required to apply formulas need not be so high as that of men who must take time studies. It is thus possible for a plant to have a few expert time-study men who will do all of the work discussed in Part I of this book and who will also compile all formulas. The rest of

the work, that of setting time values from formulas, may be carried on by men better fitted for routine work and incidentally commanding less salary. In passing, it might be mentioned that such a set-up provides a direct line of promotion within the time-study organization. Good men are willing to accept the routine job and will maintain an interest in their work if they know that they will have a chance to advance to the more highly paid more interesting time-study and formula work as soon as they have fitted themselves for the job.

Formulas have made possible the application of time-study methods and incentive plans to the job shop. Without them the cost of establishing time values would offset the savings which incentive plans produce, great as they are. With formulas, a large volume of time values may be set by a comparatively few time-study men with a large net saving to the plant. Indeed, formulas are highly profitable on all but strictly standard work where operations are so few that it would take longer to compile formulas than to set values by actual time studies.

Where all time values are set by time study, some inconsistencies are almost certain to appear. Because of errors in judgment, unnecessary work that was allowed to pass unnoticed, and variations in the judgment of several time-study men who handled the work over a period of time, some time values will be easier to meet than others. Simple jobs will, in some cases, have higher time values than much harder jobs upon which more work must be performed. Such inconsistencies tend to decrease the respect of the workers for time study and time-study methods. It takes but one or two "wild" values to shake the confidence that hundreds of correct values have built up.

The only chance for inconsistency when time values are set by formula is in an error in determining the variables which will be substituted in the formula or in the mathematical solution of the formula. Usually such slips will give time values so far out of line that the time-study man will see at once that he has made an error and will check his work. If a wrong value does get as far as the worker and he complains, it is a simple matter to recheck the job and determine whether or not the complaint is justified. Once the worker has been satisfied with the fairness and accuracy of a formula, he will very seldom ask for a recheck of a job unless he is reasonably sure that an error has been made.

If no formulas are available on a certain class of work, the time-study man has a difficult time giving accurate labor estimates on contemplated new work. He must take the drawings of the new parts, try to visualize what operations must be performed, and then estimate how long it will take to do each operation. His estimates will be little better than guesses, although he tries to use his best judgment in making them.

If formulas are available, the time-study man is able to give estimated time values, which, in the majority of cases, will be the same as the actual values which will be set when the job comes through the shop. He will get what information he needs from the drawings and will use his formula in determining time values. Unless the drawing does not give him all the information he needs, he will arrive at exactly correct time values. The importance of having accurate labor estimates becomes readily apparent when it is realized that the sales department is guided by factory costs in making bids for new business. If the cost furnished is higher than it should be, the price offered will be high, and the company will not obtain the order. If the estimated cost is lower than the actual cost, the company will very probably get the order and be obliged to fill it at a loss.

Scope of Formulas.—It is thought by those who have but a superficial knowledge of formula work that formulas can be applied only to machine work where feeds, speeds, depth of cut, and the like are the only variables. The fields in which formulas have been successfully applied are, however, very much broader than that. Practically any line of work may be formulated accurately if sufficient data are first collected. This statement may appear rather broad to those who have not dealt intimately with formulas, but glance for a minute at some of the operations upon which time values are being set daily by formulas.

All kinds of machine work.
Bench fitting and assembling.
Wiring.
Panel mounting.
Bench, machine, and floor molding.
Bench and machine core making.
Casting cleaning.
Foundry furnace work.
Metal ratios or yields.
Arc welding.

Drop forging.
Chipping with air hammer.
Coil winding, taping, and insulating.
Copper forming (miscellaneous).
Motor assembly.
Structural metal assembling.
Painting.
Window washing.
Janitor work.
Maintenance work.
Wooden-box making.
Storeroom work.
Tool making.
Pipe fitting.

These examples should suffice to show the practically limitless scope of formulas.

Characteristics of a Formula.—A formula, above everything else, must give accurate time values. If it does not, it is practically valueless. It does not do, where avoidable, to construct a formula which will give time values too low in some cases and too high in others, even though when averaged the time values are about right. The workers will continually complain about the low values and minimize the balancing effect of the high. They rightly wish every time value to be correct. If the formula is not accurate, it is very difficult to convince the workers of the fairness of establishing time values in this manner.

Very often trouble is encountered by trying to set time values on jobs to which the formula does not apply. If a job is encountered which is too large to come within the limits of the curves which are used to show variable relations, it is a temptation to extend these curves and establish a time value accordingly. In many cases, the resulting time value will not be correct. Thus the class of work to which the formula applies should be clearly stated, and all jobs which fall outside of this class should be covered by other formulas if numerous, or time studied individually if few.

A formula, in order to be quickly and easily applied, should be as clear and concise as possible. All constant elemental operations that occur on every job should be summed up into one general constant. The variables should be expressed as simply as possible. A later chapter will show various ways of expressing variables in table, curve, and chart form which will greatly simplify the task of applying the formula. All percentages that are to be added should be included in the formula constants and

variables and should not be left dangling at the end of the formula expression to be added by a separate extra multiplication. Such simplification will not only save considerable time for the routine man who is applying the formula, but it will also reduce the possibility of clerical errors.

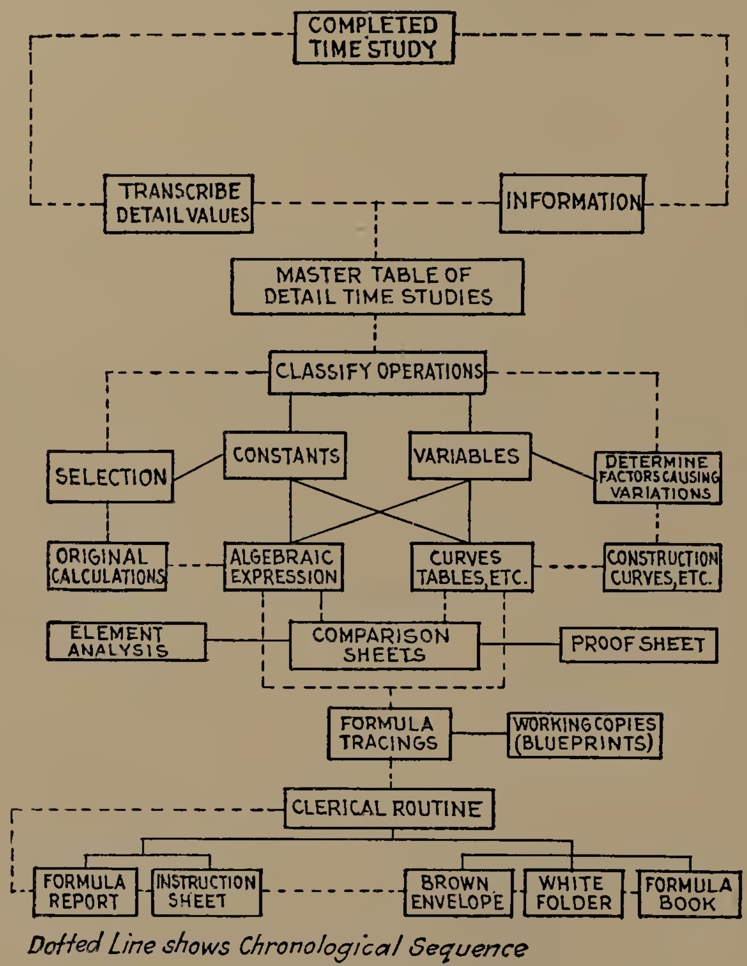


Fig. 39.—Graphic analysis of elements of a formula.

Elements of a Formula.—The first step in compiling a formula is the making of a general analysis of the work to be covered. This analysis is similar to that made when taking an individual time study, but it is somewhat broader in that it covers the class of work as a whole and not merely the individual job.

After a clear idea has been formed of what the formula will cover and what work its construction will entail, the next step is the actual collecting of data. This consists of taking detail

time studies on a number of representative jobs. These data are then assembled into a Master Table of Detail Time Studies, as will be described fully later.

There then comes the task of classifying each individual elemental operation as either a constant or a variable. Just which it is is not always readily apparent, and it requires a man of no little analytical ability to do this work. After the elemental operations have been classified, it is necessary to select a definite time value for each elemental constant and to make a further analysis of each elemental variable to determine just how and with what it varies.

When all constants and variables have been determined, there remains only the task of expressing the formula in its simplest terms and making a report which will explain clearly the construction and application of the formula.

In order to aid the visualization of the relation to one another of the various steps taken in compiling a formula, the chart shown in Fig. 39 has been made. Each step is taken up and fully discussed in detail in the succeeding chapters.

CHAPTER XIX

GENERAL ANALYSIS AND SURVEY

Before taking a time study, it is necessary to analyze the job, and similarly, before starting to collect data for the compilation of a formula, a general analysis should be made. The latter analysis is, from its purpose, broader than the former. It embraces all the details of the time-study analysis from the wider viewpoint of the formula, and it includes some details not heretofore considered.

The analysis should be made before data are collected in order to insure that all necessary and only necessary data be obtained. It is perfectly possible to make the analysis during the actual steps of formula construction, but it will be found that much effort is expended uselessly. In this chapter is set forth the procedure for making a general advance analysis and survey in preparation for the making of a formula. The steps in this procedure will be found to overlap in practice, but they are here given in as nearly chronological order as possible.

Determining the Field of the Formula.—First of all it is necessary to determine the field to which the formula is to apply. This may not be done entirely in advance, but the field may be narrowed to one general class of work. For instance, it is decided to place molding work in a foundry on an incentive basis. The time-study man surveys the molding work as a whole and discovers that by far the greater part of the work is done on vibrator molding machines. In order to gain the greatest results, he decides to formulate vibrator machine molding work. Thus he has determined in a general way the class of work to which the formula will apply, although he may later find that certain considerations make it advisable to limit the formula to jobs made in two-part flasks and to cover other kinds of vibrator machine work by other formulas. Similarly, other fields of work would be mentally determined, such as sensitive drill presses, engine lathes, band saws, blacksmithing, or panel wiring, leaving the actual limits of application to be fixed after more detailed study.

Inspection Requirements.—Inspection requirements must be determined as in the case of the individual time study, so that the time-study men may know definitely just what operations must be performed and what standards of accuracy, finish, and the like are to be maintained. He views the requirements considering the work as a whole and carefully considers whether or not they are suitable to insure work of good quality without going to wasteful extremes. The thoroughness with which he must consider the inspection requirements depends upon the nature of the work. The foundry inspector requires that a casting when molded and poured be filled out in all its parts, that it have no shifts or sections out of place due to washed sand or cores, that the metal be right, and similar simple fundamental requirements so obvious as to require little or no examination on the part of the time-study man. On the other hand, the requirements for bench fitting and assembly of a varied line of apparatus are many, and the time-study man must spend considerable time studying them and considering their justness.

Mental Study of the Operation.—After the time-study man has satisfied himself that the inspection requirements are as they should be, he should make a thorough mental study of the operation itself. He must become familiar with the methods used in doing the work in order that he may plan how best to formulate it. This mental study is made merely by observing the work as it is being done. The time-study man will observe each elemental operation and consider why it is necessary. He will assure himself that each operator is using the best methods, and if there is any variation, he will determine which is the best. If he has previously been establishing time values on this work by time study, he will already have a good working knowledge of the operation, but he should nevertheless spend some time considering the work as a class. It is very possible that he will discover certain points that have passed unnoticed before when he was concentrating on single jobs.

Survey of Conditions and Recommendations for Improvements.—At the same time that he is making a mental study of the operation, the time-study man will be making a survey of conditions. First, he will note working conditions such as light, heat, ventilation, and location of drinking fountains. He will more especially study material-handling conditions. He will note how raw material is brought to the worker and how the

finished product is removed. He will investigate all material-handling equipment, and he will study the machine equipment itself. Again he studies the points which have been dwelt on at some length in Chap. V but from a more general viewpoint.

This general survey will in most cases reveal conditions which may be bettered. Improved handling devices, convenient location of supplies, and devices which will eliminate fatigue and speed up the work will naturally suggest themselves to the time-study man. When he was completed his survey, he should recommend all of these changes to the proper authority. This recommendation may be verbal in the case of a few minor improvements, or it may be in the form of a formal report including estimated costs and savings where the changes are more comprehensive.

The general survey may not amount to much where conditions have been carefully considered before, or it may be the major part of the work of making the formula. For example, when a group of men melting and distributing metal in a foundry were studied, the general survey revealed that many devices could be installed which would make the work easier physically and at the same time reduce the size of the furnace crew. These devices were carefully worked out, and a report was drawn up showing what should be done to improve conditions. The report was discussed at considerable length by those concerned, and finally it was agreed to adopt certain of the recommendations. Some new equipment had to be designed and built, and it was nearly a year from the time that the original survey was made before conditions were improved. After that, it required only about 2 weeks of actual time-study work before the formula could be drawn up and the work put on an incentive basis. The furnace operation had been a strictly day-work proposition and little attention had been paid to conditions. The time-study man was in this case practically a pioneer, and the part of his work which brought about the biggest saving was the making of the general survey and the writing of the report.

Enlisting the Interest and Aid of the Worker.—If the workers who are to be studied have never worked on an incentive basis before and if they are entirely unfamiliar with time-study methods, they must be approached at first in the manner described in the early part of this book. After they have learned something about the fairness of time-study work, they may be further told

about the purpose of making formulas and the advantages to all concerned of establishing time values in this way.

Where workers have already been working under incentives established by time study, the purpose of making the formula may be explained without any introductory remarks. This should be done after enough mental study of the operation has been made to enable the time-study man to talk intelligently about the work. If the time-study man starts to study work upon which values have already been established without explaining his reasons, the workers are very likely to feel that the purpose of the study is to reduce time values and earnings, and they quite naturally will resent it. If, however, the time-study man explains that he is collecting data from which he will eventually be able to establish consistent time values on all jobs and if he guarantees that earnings will be unaffected if effort is maintained, the workers will have no cause for suspicion. Some may wish to know how he proposes to do this, and then the time-study man can explain briefly the general principles of formula construction, using simple examples drawn from the work on which his questioners are engaged which they will readily understand.

Not only should he thus arouse interest in the work which he is doing, but he should also encourage any suggestions on the part of the workers about improved methods or conditions. The time to make changes is before the formula is put into effect. Subsequent changes will be more costly, for then all time values must be revised. The workers will often have valuable ideas concerning the improvement of working conditions, for they realize through intimate contact any retarding factors which may exist. The time-study man, by working out these ideas and in having them put in effect, will not only benefit the employer, but he will win the lasting good will of the workers.

Trial Motion Study.—The last step before the actual taking of time studies is the making of a trial motion study. All time studies are later to be recorded on a Master Table of Detail Time Studies. By comparing the time taken for a certain element on one study with that taken on other studies, it is possible to determine whether or not the elemental operation is a constant, and if not, how it varies. In order to make this comparison, it is necessary that the operation be divided up into its elements in the same way on all studies. For example the elemental operations "get part from table," "place in fixture," and "close

cover" all should be divided as given on all studies and not appear as "get part from table and place in fixture" and "close cover" in one study and "get part from table" and "place in fixture and close cover" in another. Such a variation in motion study will more than double the work of compiling the formula and will seriously affect the accuracy of the results.

A motion study should first be made on a job selected at random, dividing the operation into as small elements as is consistent with accuracy. This motion study should be considered carefully, and the attempt should be made to keep constant and variable operations completely separated, in so far as analysis will show the operation to be constant or variable. Other jobs should be considered in the light of the trial motion study, until finally a sequence of operations is determined which will be applicable to all jobs.

CHAPTER XX

COLLECTING AND TABULATING DATA

The general analysis and survey puts the time-study man into a position to collect data with the minimum amount of wasted effort. During the analysis, he should have formed a clear idea of what data it is necessary to secure. He has taken steps, as a result of the general survey, to have all bad conditions corrected. Such changes as the management is willing to make have therefore already been made, and other changes must wait until funds, time, or opportunity bring about a more propitious occasion. There is now nothing else to be done before the actual gathering together of time studies is begun. As has been said before, analysis continues throughout the construction of the formula, but it is interwoven with other steps of the work.

Collecting of Studies Available.—Wherever incentive plans are used, there are usually several time studies which were taken to establish the existing time values and which will be of use as data for formulas. After the time-study man has made his general analysis and survey, he should select from the time-study files all studies which apply to the work to be covered by the formula. Quite often there are sufficient studies available to furnish all the data required, but unless a good portion of them were taken by the man who is making the formula, it will be advisable for him to take a few, the number depending on the complexity and variation in the work, so that he will be better able to use intelligent judgment in his analysis, classification, and selection of values. The studies which are available may have been collected over a comparatively long period of time. In this event, it is probable that conditions, methods, or equipment have changed, and unless the information on the back of the time studies is complete and definite, it will be better if the studies are not used except for comparison purposes.

Where the studies available are satisfactory in every respect, they will be a great help in several ways. They will shorten the time required to collect data, they will cover a more satisfactory

period of time, and they will generally cover a larger number of operators and a greater variety of jobs.

Taking New Time Studies.—If there are no studies available which are satisfactory for formula compilation, the time-study man should concentrate his attention on studying representative jobs until he has collected sufficient data. By representative jobs is meant types of work having characteristics similar to those of the work which will be covered by the formula. For instance, in studying the sawing to shape of composition material on band saws, it will be found that there are a number of jobs upon which only straight cuts aided by guides are taken. On others, straight cuts guided by templates are taken, and on still others radii are cut either by template or from layout. A number of jobs will be studied in each class which embrace the general characteristics of that class. Parts varying widely in size, shape, and thickness of material will be studied to insure the collecting of sufficient data to determine intelligently the amount by which these variable characteristics affect cutting time.

The number of studies which should be taken depends upon the nature of the work. Nothing should be left to judgment alone but rather all conclusions should be based on actual data and facts. If all jobs are very nearly alike, only a few studies need be taken, while on the other hand, if the work ranges widely in its variable characteristics, it will be necessary to take more. In general, the greater the amount of data collected, the easier it will be to determine constants and variables correctly and the more accurate will be the formula. Three points taken from data collected on jobs which vary widely in the characteristics being studied is the minimum number through which a curve should be plotted, but more are highly desirable. If only three points are used, one "wild" value may seriously alter the shape of the curve, whereas if more points are available, values that are incorrect will be easily detected and discarded.

In taking the studies, the time-study man should be eareful to split up the operation into its elements in accordance with the motion study which he has previously decided is the best to use. Too much stress cannot be placed on this point, for if the same division of elements is used throughout the studies, the subsequent derivation of the formula will be comparatively easy and the results accurate and reliable.

It is always a good thing to study a number of operators during the course of collecting data instead of picking out one or two good men and basing everything on them. By studying a number of operators of varying skill and leveling all to the average man, more confidence will be instilled into the workmen who will work under the formula. It will also prevent any claims that all values are based on the best men and ideal conditions.

The procedure used in taking time studies for the purpose of compiling a formula is exactly the same as that used in taking studies to set individual time values. This has been set forth in detail in the first part of this book, and no further elaboration is here needed.

Accuracy, which is at all times important, is especially so when collecting data upon which a formula is to be based. If an error is made when taking a study from which an individual time value is to be set, only that value is affected, and the seriousness of the consequences depends upon the magnitude of the error and the activity of the job. If an error is made when data for formula use is being collected, every value set from that formula will be affected. Even a small error may assume serious proportions when it affects every job on a given class of work. Therefore, the time-study man cannot be too careful in collecting and working up his data, and every minute spent in checking up the accuracy of his work will be time profitably spent.

The number of pieces studied on any job depends, of course, on the nature of the work. Care should be taken to study enough to insure that the resulting values are representative. Formulas which are based on studies made on one or two pieces are generally inaccurate and subject to much criticism. On some lines of work where the operation cycle is unusually long and where the work comes through the shop in small quantities, it is impossible to get more than a few pieces on any job. In such cases, more jobs should be studied. When the time studies are later lined up on the Master Table of Detail Time Studies, it will then be possible to recognize unrepresentative time values because of their variation from the majority of the other values.

Collecting Data for Allowances.—The allowances which are given to care for fatigue, personal necessities, and unavoidable delays are the same for formula work as they are for individual time studies. The manner in which these allowances are determined has already been given in Chap. XIV. Special allow-

ances, however, are used more in formula work than on work where time values are established by time study, usually because a more thorough study of existing conditions is made when collecting data for formulas. Three general classes of operations are commonly covered by special allowances in compiling a formula: work which occurs periodically and which is usually done as day work, work which occurs intermittently and irregularly, and work which could be handled by definite values in the formula but which would so complicate the formula expression that the labor involved in establishing time values would not be offset by the accuracy gained.

In some cases all three classes of special allowances are used in the same formula. A good example of this is found in a formula covering machine core making. An operation which occurs periodically is cleaning sand out of the machine at night and refilling and oiling the machine in the morning. This was formerly done as day work. The amount of time spent in 1 week on this work was determined by time study, and it was a simple matter to distribute this time over each time value by increasing formula values by the percentage of cleaning and oiling time to productive time.

After the cores are made, they are dried on a continuous conveyor oven. It is quite possible definitely to determine handling time for each core to and from this oven, both before and after blackening, but it involves the introduction of so many terms into the final formula that it is far easier and nearly as accurate to handle the small amount of time involved by a percentage figure. Before blackening, it is necessary to file off any fins that may be on the cores and to fill up any irregularities with black lead paste. Many things such as the nature of the core, the condition of the core box, the skill of the operator, and the use of the finished casting affect this smoothing time. It is practically impossible to express this time other than by a percentage figure determined by a series of all-day studies covering a wide range of work. In such cases as these, it is perfectly proper to establish special allowances. Care must be taken not to carry this practice to extremes and not to use allowances where the accuracy of the time values will be seriously affected. It is important that all special allowances should be determined by comprehensive studies and not merely determined by an estimate.

Recording Information.—Complete identifying information of each job studied should be recorded on the back of the time-study sheet. Good practice recommends that this should be done even though the study is to be used only for setting a single time value. In such cases, however, the details of the job are fresh in the mind of the time-study man, and he may be well able to set the time value without referring to any recorded information. For the purpose of establishing individual time values, then, complete information is not absolutely essential, although its lack renders the study valueless for future reference.

Time studies that are to be used for formula compilation may be taken several months before they are so used. Therefore their subsequent value is directly proportional to the completeness of the recorded descriptive data. A record of the drawing number, pattern number, or other shop identification makes it possible to locate the job if at any future time it is desired to check data already taken or to secure information which had been previously overlooked. A clear description of any unusual features which occurred during the taking of the time study will aid in explaining unexpected variations in the data.

It is absolutely necessary to have a complete sketch of the part and a complete record of all dimensions. Variable time elements will depend on variable job characteristics, and in order to determine the nature and magnitude of the variation, the time-study man must have sufficient data. If it is not given by the dimensioned sketch, he will have to refer to the engineer's drawing of the job.

Tool, jig, and fixture information should be given in detail. Sketches showing the manner in which the operation was performed such as Figs. 22 and 23 will prove helpful when working up the formula. In brief, it may be said that a description of everything having to do with the job itself and with the method of performing the operation should be completely and clearly recorded on the back of the time-study sheet at the time the study is taken.

Review and Correlation.—When the time-study man feels that he has collected sufficient data, he will find it very profitable to spend a few days watching the performance of the work without actually taking any studies. During the time he has been making the studies, his attention has of necessity been concentrated on each job that he studied. He has had little chance to

view the work as a whole, and it is quite possible that important considerations have hitherto escaped his attention. Through his time-study work, he has gained an intimate knowledge of the work which he did not possess before. Thus he is in a good position to review what he has learned and to see just exactly what must be done to perform the work successfully.

While he is watching the work and making what may be called a mental synthesis, he will have ample opportunity to talk with the foreman, workmen, and others who are familiar with the details of the work. He will, without being aware of it at the time, secure much information which will later be of value to him. The reasons for everything which is done should be readily apparent to him, and he will gain a more intimate knowledge of existing conditions.

The amount of time which should be spent on this phase of the work will depend on the complexity of the operation and upon the familiarity of the time-study man with the work. When he finishes the review and correlation, he should feel thoroughly familiar with all of the details of the work and he should have gained, in a general way, an idea of the form of the final formula.

Master Table of Detail Time Studies.—Reference has been made several times to the Master Table of Detail Time Studies. Before passing on to the tabulation of data, it will be well to give a brief description of this important form. A Master Table compiled for a sample formula is shown in Fig. 58. It is 22 by 17 inches in size. When folded once in each direction, it may be conveniently filed with standard $8\frac{1}{2}$- by 11-inch papers.

In the upper left-hand corner, space is provided for identifying the sheet to the formula. Experience in trying to locate unidentified Master Tables will prove the value of completely filling in this part of the form. Under this space is a wide column headed Operation Description. Here will be recorded the name of each elemental operation. The columns to the right under *S*-1, *S*-2 and so on, are used for recording the time data taken from time studies. The top part of these columns is devoted to a description of the characteristics of each job.

The purpose of this form is to enable the time-study man to tabulate his data so that they will be convenient for the analyzing of each elemental operation. He has before him the characteristics of each job and the time for performing each elemental operation on each job. He can see at a glance which operations

are performed on every job and those which are performed only in special cases. He will easily be able to review the time taken to perform a certain operation on every job, and he will readily see whether that operation time is fairly constant or not. If the attempt were made to use the data which have been collected directly from the time-study forms upon which they are recorded, the work of compiling the formula would be increased many times and the final accuracy would be seriously affected.

Posting Data on Master Table of Detail Time Studies.—All usable data should be posted on the Master Table of Detail Time Studies. Values which the time-study man is satisfied are incorrect and operations which are obviously unnecessary should not be posted. The tabulation should be made neatly and preferably in ink. Under Operation Description is recorded the name of each elemental operation. The space set aside for Job Characteristics should show the date upon which the study was taken, the name of the operator studied, and a complete record of job identification and variable job characteristics. On some classes of work, a small neat sketch of the part may be made at the bottom of the Job Characteristic space.

In the Elapsed Time columns is posted the leveled time value with allowances added for each elemental operation for each time study. Thus a vertical column in connection with the Operation Description is a list of the time values which occurred in one particular study. A horizontal line is a list of the time values which occurred on every time study for one particular elemental operation.

It is not necessary to list the elements in the order of their occurrence. When the first study is posted, the elements will be tabulated as they occur. For the succeeding studies, whenever an element occurs that occurred in the first study, the time value is posted opposite the corresponding operation description. Otherwise the name of the element must be given a separate line.

The columns headed Symbol, Allowed Time, and Reference are filled out when the allowed time is determined. Each elemental operation should be given an alphabetical symbol. These symbols should be assigned as nearly as possible in the order in which the elements occur. As each constant allowed time is determined, it should be recorded in the Allowed Time column, and the study or studies in which the selected value occurred should be noted under Reference. If the operation is a

variable, the curve or table which handles it should be recorded. If there are more than 26 elemental operations, the alphabet may be repeated with subscript numbers as A_1, B_1, and so on.

At the extreme upper left-hand corner the following heading will be noticed:

Sheet——
of——sheets.

This should be filled out to read as Sheet 1 of 3 sheets if more than one Master Table form is used. Thus if referring to the Master Table at any future period, one may be sure that he has all of the sheets that were used.

The actual work of posting is simple enough to delegate to a clerk working under the supervision of the time-study man. Like everything else connected with time-study and formula work, it must be done accurately, and the figures posted on the Master Table should be carefully checked before going ahead with the formula compilation.

CHAPTER XXI

CLASSIFYING OPERATIONS AND DETERMINING CONSTANTS AND VARIABLES

When all time values have been posted from the time studies to the Master Table, the time-study man is ready to choose values which will be used in the final formula. As has been mentioned before, there are two general classes of elemental operations; first, those operations which are exactly the same regardless of the characteristics of the job and, second, those which vary in method or time of performance with variable job characteristics. In many cases, it is fairly easy to determine whether or not an elemental operation is a constant. In others, there will be a wide variation of the time taken for doing the operation on different jobs, and the reason for this variation may be somewhat obscure. Considerable analytical and mathematical ability is necessary to trace the reason for such a variation to its source and to determine exactly how the time required for performing the operation is affected.

Preliminary Analysis.—Before actually classifying elemental operations as constants or variables, a preliminary analysis of the data on hand should be made. It is well to note if a representative number of operators who are engaged in performing the class of work under consideration have been studied. Theoretically, it should be possible to arrive at the same results if only one or two men are studied, since the use of the leveling principle brings all time values to the plane of the average man. If the time-study man is an expert and is thoroughly familiar with the work, he will no doubt be able to do this, but actually it is better to study a number of different operators. Not only will the time-study man thus have a check on his judgment and upon methods employed in doing the work, but he will also find it much easier to convince supervisors and workers that his time values are truly representative.

If the data collected on an ordinary simple operation extend over several sheets of Master Tables and if the same elements

appear to be repeated on only a few of the different jobs, it is reasonably certain that the time-study man did not divide the major operation into its elements in the same manner for the various studies. If such be the case, it is rather difficult to get the data into usable shape. By dint of combinations, subtractions, and simultaneous equations, it may be possible to resolve the data into a more compact form, but unless these data appear to be fairly consistent for the different jobs, it is better to throw away all that has been done and make a fresh start aided by the experience gained. Such cases happen usually only when a new time-study man is making his first formula. Thereafter, he has a better idea of the form that final data should assume, and he chooses his elemental operations accordingly.

A good set of data should have a compact appearance on the Master Table. There will probably be some few operations that were performed on only one or two jobs and there will be others that occur only on jobs having certain characteristics, but for the majority of operations a time value should appear on each study.

Classifying Operations into Constants and Variables.—The time-study man is now ready to review each elemental operation separately and to determine whether it is a constant or a variable. Pure analysis will generally be sufficient to tell an experienced time-study man whether or not an operation should be constant on all jobs, but he should also be guided by the data. If analysis shows that an operation should be constant and if the time values appear to be of the same magnitude with only a slight variation between the minimum and the maximum, then it is safe to classify that operation as a constant. Similarly if there is a wide range between the minimum and the maximum time values on an operation which analysis shows should be variable, it is again proper to classify the operation accordingly. It is only in those cases where analysis and the data do not lead to the same conclusions that the time-study man need hesitate. He will usually find an unexpected variation in the time taken for doing an element which he expected to be a constant rather than the opposite: He will find it necessary to review his time studies in order to find out the reasons for an unexpectedly high or low value. If he can find no satisfactory explanation, he must observe the operation as it is being performed and perhaps even make additional time studies. In the end after he has collected

sufficient data and has given sufficient thought to them, the time-study man will practically always reach a satisfactory conclusion as to the nature of the operation.

As each operation is classified, it should be marked with a small *c* or *v* to identify it definitely as a constant or a variable in the future. Miscellaneous operations which occur only once or twice throughout all the studies should be marked with an *m* and left for consideration until after the magnitude of the constant and variable operations has been determined.

Choosing Constants.—After the elements have been classified into constants and variables, a time value must be selected for each element that has been recognized as a constant. The values obtained from the several studies for a given element may vary considerably, often as much as 100 per cent. This is because of errors in judgment on the part of the time-study man as to the skill and effort displayed by the operator, variations in conditions under which the work was done, differences in the efficiency of the machines, and so on.

In order to make an intelligent selection, the time-study man must know the actual conditions under which the job was worked, he must know the ability of each operator intimately, and he should be acquainted with the equipment and the kind and condition of all materials used. All time studies that do not give fully this information should be used only as a means of comparison. If the time-study man knows all that is necessary, he will be able to make a selection from the several elements listed on the Master Table. Beginning at the left-hand side of the table, he will run over to the right carefully, comparing each value with the others and mentally noting the conditions under which the value was obtained. After having carefully studied and compared them, he will make his selection. The selection should be the time that an average man engaged on this line of work can perform the given element working at an average rate of speed with average working conditions. When the value has been selected, it will be recorded in the column provided on the Master Table together with the number of the study from which the value was selected.

The value which is chosen should be, where possible, one which occurs several times on different studies and which is about midway between the minimum and maximum values. If sufficient data have been carefully collected, such values will be found

in the majority of cases. Where there is an unexplainably large variation and where no value is repeated in two or more studies, all values should be averaged, and the actual value which is closest to this average value should be used. Actual values should be used rather than average because of the psychological effect on those to whom the formula must later be sold and to facilitate reference.

Analysis of Variables.—Choosing constants is a comparatively simple matter, but the determination of variables requires keen judgment and good analytical ability coupled with a knowledge of algebra and the principles of curve plotting. In this phase of time study and formula work, the technically trained man usually outstrips the practical man because of his familiarity with various mathematical devices.

Each variable element must be considered separately and the means of handling it determined to fit the individual case. Probably the simplest way of handling variables is to divide the work as a whole into several classes and to select a constant value for each class. For example, the time required to lift a part from a tote pan to the table of a drill press is found to vary in a general way with the size of the part. In this case, sufficient accuracy will be obtained if the work is classified as small, medium, and large, and if three values are selected from the data, one for each class. If the drill-press work covers a very wide range of sizes, it may be necessary to add two more classes, such as very small and very large. The time-study man in making this classification will determine the approximate limits of weight and volume for each class and will include them in the final formula report as a guide to those who will apply the formula in the future.

Similar classifications may be made for operations upon which time varies with the complexity of the job. It will be noticed that the work covered by the molding formula in Chap. XXIX has been classified as simple, medium, and complex and that definitions of the characteristics pertaining to each class have been given.

Expressing Variables in Curve Form.—Variables are probably expressed more conveniently in curve form than in any other way. Indeed, the time-study man will find the plotting of curves a great help during his analysis of variables regardless of how he decides to handle the element in the final formula.

The variable job characteristic with which the time for performing a certain operation varies is not always readily apparent. In such cases, a series of experimental curves should be plotted to show how time varies with each variable characteristic which would be likely to affect it. On one curve, the points will probably line up better than on any other, and if analysis does not point to the contrary, it may be safely assumed that this is the proper relation to use.

Points for curves plotted on such things as machine time will usually line up very nicely and definitely mark the proper direc-

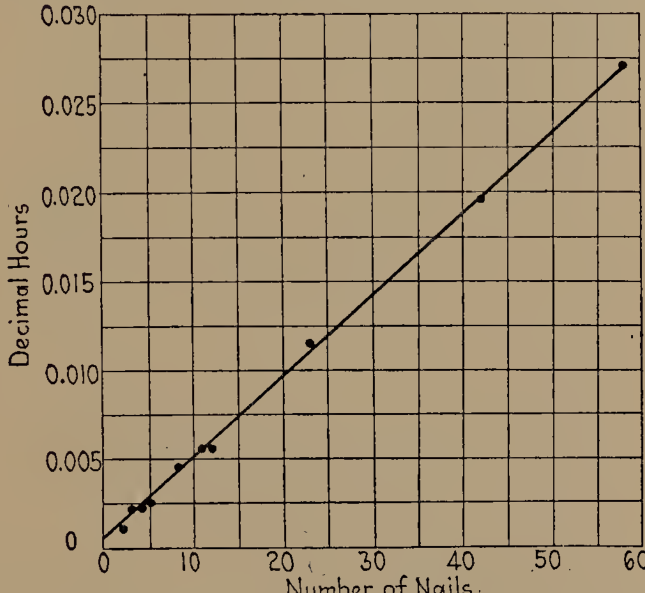


FIG. 40.—Curve plotted from data collected on time required to set nails—point down.

tion of the curve. Points plotted on operations which are largely affected by human skill and effort will more often show a wide range, and a technically trained man making his first formula is quite likely to feel rather discouraged when he tries to plot his data. If he will stop to consider how many minute things practically impossible of detection may affect the time taken and if he realizes that skill and effort range in a series of infinitesimally small steps from a minimum to a maximum whereas the leveling method only recognizes six classes for practical purposes, he will not wonder that such data do not plot up as smoothly as a speed-torque curve or a load-efficiency curve. Data secured on human effort will if properly obtained plot up

well enough to show definitely the trend of the curve, and the time-study man, aided by judgment, will be able to draw what will be a very nearly correct curve.

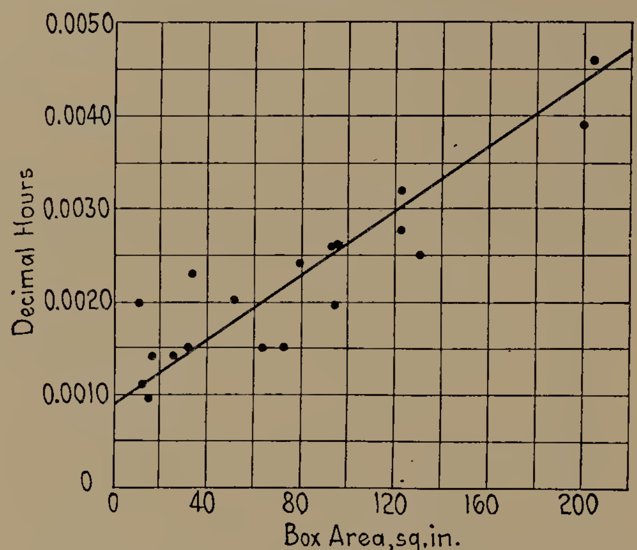


FIG. 41.—Curve plotted from data collected on time required to place box on table.

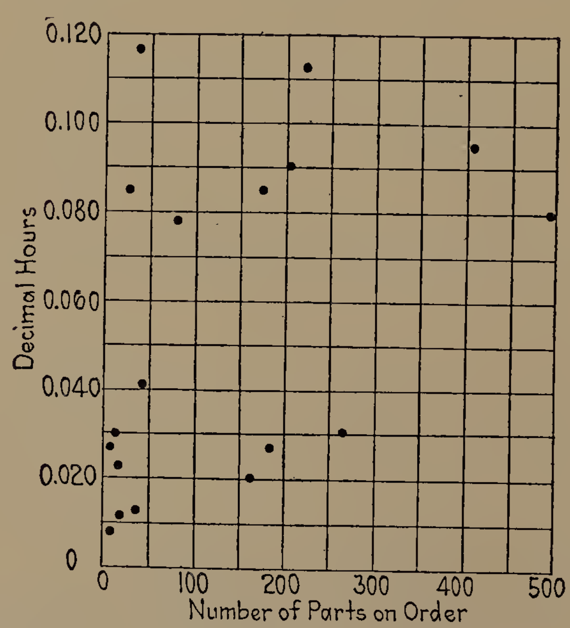
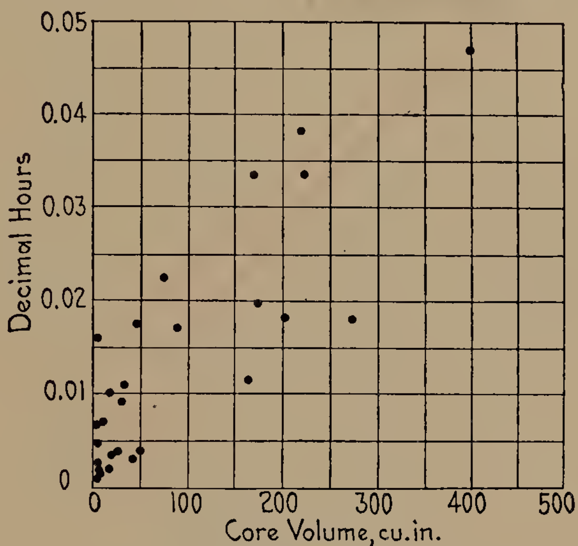


FIG. 42.—Points plotted from data collected on time required to draw material from bin.

The curve of nailing time against number of nails shown in Fig. 40 shows about as good a set of points as may be expected.

More often points will appear as shown in Fig. 41. The variation here is not too great, however, to show definitely the trend of the curve. The points shown in Fig. 42 are dotted all over the paper and prove conclusively that the time required for performing the operation of "draw material from bin" in a storeroom does not vary with the number of pieces on the order.

Expressing a Relation between Three Interdependent Variables.—The time-study man will very often find that the time for performing a certain elemental operation is affected by two variable job characteristics, and it will be necessary to take them



SEE OVER

FIG. 43.—Points plotted from data collected on time required to fill core box with sand and peen—core volume in cubic inches vs. decimal hours.

both into account in some manner. The simplest way is to classify one of the variables as small, medium, or large, or smooth surfaces and rough surfaces, and then plot the other variable against time for each class. This method is perfectly satisfactory in some cases, but where greater accuracy is necessary, another way must be found.

A definite example may show how a case of this kind should be handled. For the elemental operation of "fill core box with sand and peen," analysis at once showed that filling and peening time should vary with the volume of sand handled. Accordingly points were plotted volume against time as shown in Fig. 43. It was apparent at a glance that some other factor entered in. Further analysis revealed that the relation between the height and the thickness of the core would also affect the time. Where

the thickness of the core is great in comparison to the height, all sand may be put into the box and peened at one time. Where the thickness of the core is small as compared with the height, sand must be put in a little at a time and peened frequently. It is evident then that the ratio of height to thickness affects filling and peening time as well as core volume. An attempt was then made to classify the work according to this ratio, plotting a curve for ratios up to one, another for ratios between one and two and so on. The results were unsatisfactory and this method was abandoned.

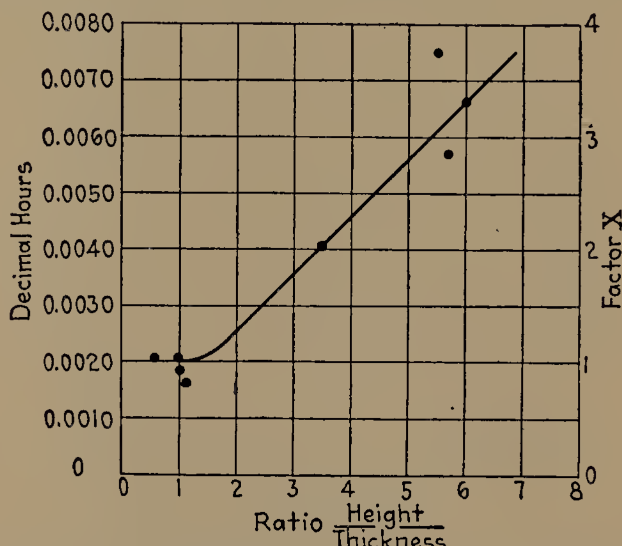


FIG. 44.—Curve of ratio of $\frac{\text{height}}{\text{thickhess}}$ vs. decimal hours for cores of from 5 to 10 cu. in. volume for operation "fill core box with sand and peen."

It was finally determined to use two curves in conjunction with each other. A curve of time against ratio of height to thickness was plotted for cores having an approximately constant volume. Since volume was constant, the curve showed a true relation unaffected by volume. This curve was plotted as shown in Fig. 44. It will be noticed that the curve intercepts the Y axis at 0.0020 hour. The time scale was changed by calling this point of interception 1, the point at which the time doubled or 0.0040 hour 2, and so on. Then in order to get a curve of volume against time unaffected by the height and thickness of the core, each time value taken from the original data was divided by a factor determined by the ratio of height to thickness of the core and read on the new factor X scale as shown in Fig. 44. These values plotted against the corresponding volumes give a

time-volume curve unaffected by the height and thickness of the core. The points now lined up into two sets of points as

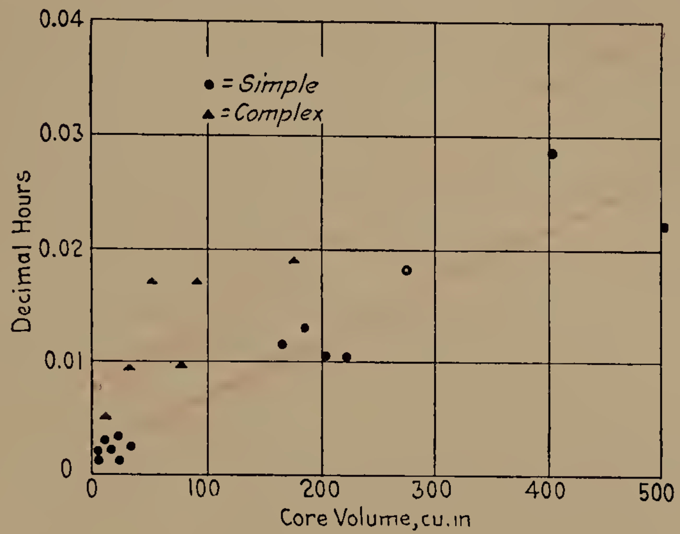


FIG. 45.—Points shown in Fig. 43 when corrected for effect of ratio of $\frac{\text{height}}{\text{thickness}}$ of core for operation "fill core box with sand and peen."

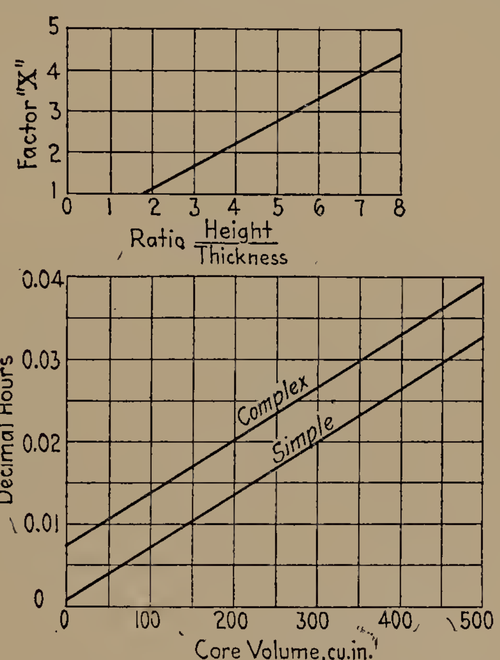


FIG. 46.—Final curve sheet for operation "fill core box with sand and peen."

shown in Fig. 45. A little further study of the data showed that the higher values were all obtained from studies on cores which were difficult to make. A further classification of jobs as simple

or complex enabled the plotting of the final curves shown in Fig. 46.

In order to arrive at filling and peening time for any core, a factor X is found corresponding to the ratio of the height and thickness of the core and a base time for the proper volume from the volume-time curve. These two values multiplied together give the true time required for filling and peening. For example, a simple core having a ratio of height to thickness of 4 and a volume of 100 cubic inches would receive an allowed time value for filling and peening of $2.4 \times 0.0092 = 0.0218$ hour.

This same principle may be applied in many instances and will be found very useful. It has been used to handle relations between perimeter of mold center block, greatest dimension of wire, and winding time as shown in Chap. XXXI and ratio of shipping weight to area, excess weight, and shipping weight as shown in Chap. XXXII.

Miscellaneous Values.—In practically every set of data compiled into a Master Table of Detail Time Studies, a few elemental operations will appear which were performed on only one or two studies. In many cases, these operations were entirely legitimate and were made necessary by some special characteristic of the particular job. At the time of classifying operations, these elements were classified as miscellaneous and marked with a small *m*.

The way to include these miscellaneous elemental operations in the formula expression depends upon the nature of the operations. If an operation is caused by a variation in material such as removing a piece of metal left by a defective core from a casting, it is likely to occur at any time. Here it is best to determine the amount of time spent on such operations over a representative period of time and to express it as a percentage of the total time spent. Then the time for every job done under the formula is increased by the determined percentage. This practice simplifies the formula and tends towards consistency and is recommended where accuracy is not too greatly sacrificed.

Certain other operations will be found to be made necessary by a certain characteristic of the job being worked. This variable characteristic may occur on only a very small proportion of the total jobs. Therefore, in order to simplify the formula expression, it is best to include such time values in a table of Miscellaneous Values. Complete instructions about the manner

of applying these miscellaneous values should accompany the formula.

The selection of a proper time value for a miscellaneous operation requires more care than if the operation were done on every job, because there are generally but one or two values to choose from. The time-study man must review the studies from which these values were taken, and use good judgment in deciding whether or not the operation was properly performed. If there is any question of doubt about the correctness of the time value, it is best to place only the operation name in the table of Miscellaneous Values and leave the space for the time value blank until such time as the operation may have been thoroughly checked. This may not be until after the formula has been in use for some little time, since these operations occur but rarely.

Element Analysis.—A complete record of the reasoning and deductions of the time-study man in the classifying of operations, choosing of constants, and the establishing of variables, curves, tables, and the like, will be found to be very valuable. This record is known as the Element Analysis. In the element analysis, each element is analyzed carefully and completely. If it happens to be a constant, an explanation of why this is so is given. The selected values for all constants, considered separately, are explained and justified. The derivation of the curve or table for each variable element should be given and its basis justified. Every step and thought which led to the final result should be carefully recorded. If in plotting a curve different factors or characteristics from those finally adopted were tried and found to be unsatisfactory, it should be explained in the element analysis in detail. The value of such an analysis is obvious, for should it become necessary to investigate or revise a formula at any time, a review of the element analysis will give the time-study man who made the formula or any other time-study man a complete knowledge of how the formula was derived and the reasons for each elemental value. Chapter XXVII shows a complete element analysis.

CHAPTER XXII

FORMULA EXPRESSION

The formula expression is the result of all the work which has been done in the making of the formula. The first thing which was done was to collect data, the next was to analyze and classify them into constants and variables, and the next was to build up the values or to compile them into the formula. The building up of the values is done by synthesis, after which the expression is formed. The formula expression should be in the simplest possible form. Every value should be reduced to the simplest terms. It should not be the aim to make an imposing or a complicated expression, but rather to keep in mind the time which will be required to apply the formula. The routine man who uses the formula is usually a busy man, and if the formula takes what in his mind is too much time, he will short cut much of it and will probably establish many inconsistent values. The purpose and the meaning of every term in the expression should be readily understandable without referring to the formula report, and every symbol should be clearly defined in brief terms.

If space does not permit a clear definition of how and when to use any of the values in the expression, it is sometimes necessary to write an instruction sheet or set of instructions which should explain clearly and fully how and when each value is allowed and also any explanation which is deemed necessary on how to compute them.

Combining Constants.—In order that the expression be in its simplest form consistent with accuracy and time required to compute, it is necessary that all values and symbols be combined where possible. This combining process is explained under Synthesis in the Formula Report, and reference to Synthesis should show every step in the combining process. All possible combinations should be made in the building up of the formula. For example, take a simple operation, say drilling, tapping, and countersinking holes on a drill press. The formula from which the tapping time is determined will probably cover other opera-

tions such as reaming, burring, counterboring, and the like. The formula expression will contain a constant, which will be the sum of all elemental operations which occur on every drill-press operation, plus a term for drilling which considers the size of hole, the thickness of part to be drilled, and the material, and which is multiplied by the number of holes, plus a similar term for countersinking, plus a tapping term which takes into account the size of tap and the depth threaded, and other terms which cover additional handling operations. Any one of these terms is made up of several elemental time values, and the time value which is finally established is the sum of the appropriate terms multiplied by the number of occurrences.

The elemental operations may be classified as part handling, machine handling, and machining. Under part handling will be grouped such values as "pick up part," "place in vise and tighten," "loosen vise and remove part," and "lay part aside." It is apparent that these operations will occur once on each piece. Instead, therefore, of having the time for each element in the expression, the time values allowed will be added together, and one value which will take care of the constant part-handling time for vise jobs will be given in the formula expression.

Under machine handling will be grouped such elemental operations as "move to hole location," "lower spindle," "engage feed," "release feed," and "raise spindle." It is also apparent that these elements will occur once for each hole drilled and that the time must be allowed accordingly, but as in the case of part handling, it is not necessary to have in the expression the separate time for each element. The elemental times will be added together, and the total will be included in the formula expression as a single term and will be allowed once for each hole drilled. Here it is seen that one value takes the place of five. This same process of combining constants and symbols will be continued through to the completion of the expression.

It is possible to go on indefinitely with examples of combining constants, but it is not deemed necessary. The examples of formulas which are to follow will serve to illustrate how the values are combined. This point of combining for simplicity and ease of handling should be given a great deal of thought by those who are interested in formula work. The authors have had men who were not sufficiently grounded in the principles of formula construction turn in for approval formulas that were

far from being in the simplest form. After carefully analyzing the expression, it was possible to reduce its length considerably, often to half the number of terms, notwithstanding the fact that the time-study man believed that he had combined everything that should be combined.

Tables.—Certain kinds of data should be made up into tables and referred to in the formula expression by a single symbol. Tables serve to simplify the formula expression and to keep it from becoming unwieldy.

Tables of miscellaneous values have already been discussed. It is readily apparent that such values which occur but infrequently can be most conveniently handled in tabular form. The time values are thus always available when needed but need not be considered on the ordinary run of work. Additions may be made to the table of miscellaneous values whenever a representative time value for a miscellaneous operation is obtained. If these additions are made from time to time, the table will eventually become complete and will contain sufficient information to allow the establishing of all time values without the necessity of taking time studies. This, of course, refers only to work on which unusual operations may occur and for which the accuracy obtainable by a Table of Miscellaneous Values is desired. Some classes of work are so simple that no miscellaneous operations may ever occur. In other cases, miscellaneous values are so numerous that they are better covered by a percentage allowance.

Specific tables may be compiled to cover such operations as gaging. Checking and measuring the work may be done with pin, plug, ring, or snap gages or with calipers, micrometer or a scale. The gaging table will give the time allowance for each method of measuring. Similar tables may be compiled under specific heads such as a Reinforcing Table for core work or Table of Constant Machining Operations for lathe work.

Tables or charts giving time values for varying conditions of feeds and speeds may be conveniently used for machine work. An example of such a table has already been given in Fig. 21, Chap. IX.

In many cases, a relation may be expressed either by a curve or in tabular form. Figure 40 showed a curve of the time required to set nails against the number of nails set. This could also have been expressed as follows:

TABLE OF NAILING TIME

Number of nails	Nailing time	Number of nails	Nailing time	Number of nails	Nailing time
1	0.0011	21	0.0102	41	0.0193
2	0.0015	22	0.0106	42	0.0197
3	0.0020	23	0.0111	43	0.0202
4	0.0025	24	0.0115	44	0.0207
5	0.0029	25	0.0120	45	0.0211
6	0.0033	26	0.0125	46	0.0216
7	0.0038	27	0.0130	47	0.0220
8	0.0042	28	0.0134	48	0.0225
9	0.0047	29	0.0138	49	0.0229
10	0.0052	30	0.0143	50	0.0233
11	0.0056	31	0.0147	51	0.0238
12	0.0060	32	0.0152	52	0.0243
13	0.0065	33	0.0157	53	0.0247
14	0.0070	34	0.0161	54	0.0252
15	0.0075	35	0.0166	55	0.0257
16	0.0079	36	0.0170	56	0.0262
17	0.0083	37	0.0175	57	0.0266
18	0.0088	38	0.0179	58	0.0271
19	0.0092	39	0.0183	59	0.0275
20	0.0097	40	0.0188	60	0.0280

If the formula is to be applied by a man who has had little or no technical training, a table will be easier for him to handle than a curve. Tables offer less opportunity for error when used by an untrained man and thus permit the establishing of more consistent time values.

Most time-study men, however, are thoroughly familiar with curves and those who are not can be readily trained to use them. With a little practice, accuracy will be developed. Tables are, in general, more bulky than curves and often require interpolation. Where interpolation is required, the advantages enumerated above are lost.

Curves.—Curves plotted on rectilinear coordinate paper form about the simplest and most convenient means of expressing relations between variables. It is usually better to leave the curves in graphic form rather than to try to express the relation which they show algebraically. Many of the curves which are obtained in time-study work are straight-line curves. The mathematical ability needed to express such curves alge-

braically is not great, and where desirable, the curve may be reduced to algebraic form. In all other cases, unless there is a great advantage in having the algebraic expression, the graphic curve may be used satisfactorily.

Sometimes advantages result in plotting curves to logarithmic coordinates. Wherever this is the case, it is perfectly proper to use such coordinates. There are many excellent texts available on the handling of variable relations graphically which go more deeply into the subject than is possible or desirable in a book of this kind. It will suffice here merely to recommend the use of curves wherever a convenience or a saving in labor is to be gained. The examples which follow show clearly how curves are used in actual practice.

Graphic Charts.—Everyone who has had occasion to study or use steam charts realizes the great convenience which is gained by expressing the many variable relations graphically in one composite chart. The same convenience has been gained in many other lines and may well be applied to time-study work wherever practicable. Such charts will greatly aid in the quick and accurate solution of a formula expression. A good example of this is given in Chap. XXIX. Part of the formula expression, that is, $\frac{0.2959}{A} + 0.00234C + 0.0207P$, has been plotted in chart form for each classification of pattern as shown in Curves 1, 2, and 3 of the bench-molding formula. Values of A range from one to seven and of P from one to three. Thus 21 definite points are located on the chart from which curves representing C may be drawn. The ease with which the above expression may be solved is readily apparent.

Alignment Charts.—Alignment charts may be used to great advantage to multiply or divide two or more variable values. They are a great aid in computing time values which are affected by two variable job characteristics. In Chap. XXI was shown the method of expressing such a relation graphically. The final curves shown in Fig. 46 may be put into alignment chart form as shown in Fig. 47, thus simplifying the computation of the time allowed for "fill core box with sand and peen." Instead of reading four scales and performing a multiplication, it is necessary only to locate the proper points on the two outside scales, connect them with a straight line, and read the time allowed directly on the middle scale.

Many more elaborate alignment charts have been made to cover the relations between time and feed, speed, depth of cut, and the like. A chart of this nature is shown in Fig. 48. The actual work involved in plotting such charts is not great. Com-

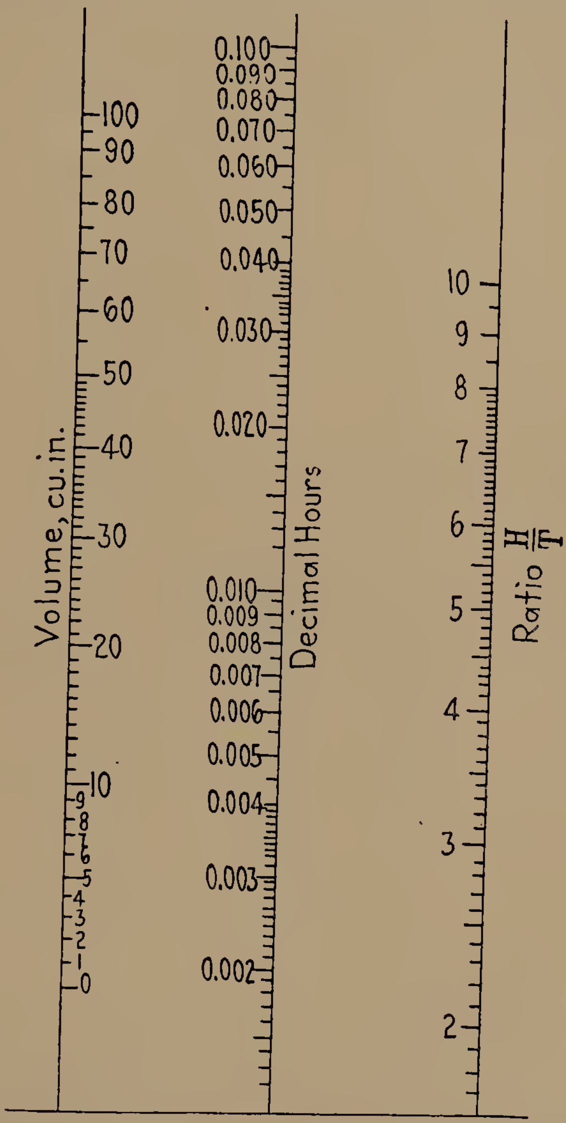


Fig. 47.—Alignment chart made for curves for simple core shown in Fig. 46.

plete texts covering methods of plotting alignment charts for many different conditions are available for reference.

The Final Expression.—When all constants have been combined and all charts, curves, and tables compiled, there remains only the task of placing them in the most convenient form for reference. The algebraic expression is usually entirely satis-

factory. It shows clearly all factors that must be considered, and it precludes the possibility of any omissions.

The constant which applies to every job, if such there be, should come first. Then follow other constants together with the symbols, which in connection with the symbol explanation, show when and how often each constant should be used. Lastly should follow references to tables and curves.

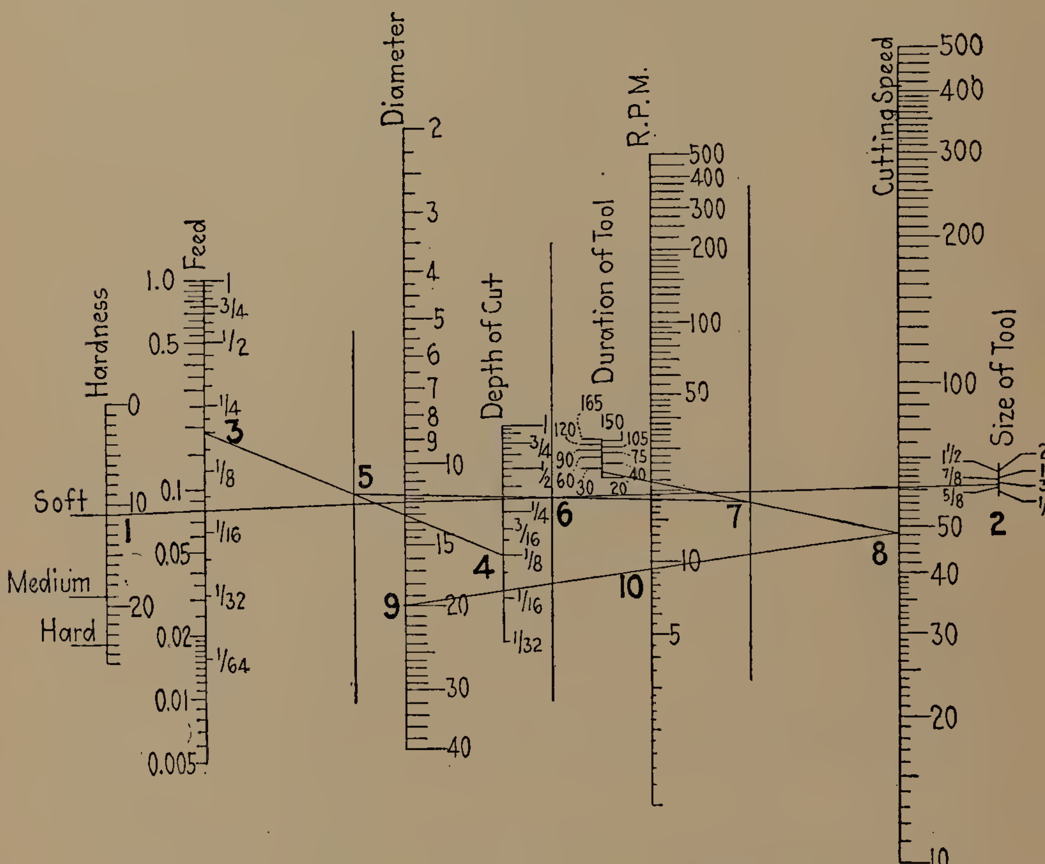


FIG. 48.—Alignment chart—cutting speeds, roughing cast iron.

The final formula expression should be in the simplest terms to which the data may be reduced. All possible combinations and contractions should have been previously made. In most cases, even for rather complex work, the final formula expression will be rather short and easy of solution. In the examples which follow, the surprising amount of condensation which is possible is clearly shown.

CHAPTER XXIII

TESTING AND SELLING THE FORMULA

After the formula has been put into its finished shape, the time-study man must satisfy himself as to its accuracy. Before he can attempt to sell the formula to anyone else, he must have complete confidence in it himself. He should have the confidence which is born of knowledge and ability, and he will then strengthen this confidence by testing the formula thoroughly under the conditions of actual use.

There are three general ways of testing a formula. The most reliable and satisfactory way is to select, from the time studies taken on the work to which the formula is meant to apply, a number of studies on various jobs which will be considered as being representative. Then for these jobs the allowed time is calculated from the formula and checked against the time derived from the studies. These studies are usually available from those taken while collecting data for the formula. The other two ways are by checking formula values against existing values established by time study and by checking formula values against time-study values and overall checks obtained for the purpose. The first method involves less actual work and is used wherever a sufficient number of time studies are available.

Checking against Existing Time Values.—Wherever any time-study work has been done, there are generally some time values established on jobs which were made at one time in fairly large quantities. These values may be conveniently used for checking a newly compiled formula. A form similar to the one shown in Fig. 49 may be ruled up to give columns for the job identification, the old time value established by time study, and the new value computed from the formula.

As has been previously pointed out, values set from time study over a period of time by different time-study men are very unlikely to be truly consistent. It is therefore not to be expected that all formula values will check exactly with all time-study values. They should, however, check closely to within a few per cent plus

or minus, and the total of the old and the new values may be expected to be very nearly the same.

When making a check by this method, care should be taken to select jobs which will test the formula from one extreme of its application to the other and not merely to select jobs which are

Drawing number	Item	Old time allowed, hours	New time allowed, hours
616369	4	0.265	0.208
633278	1	0.100	0.100
620074	2	0.260	0.210
623705	1	0.200	0.465
606339	1	0.225	0.199
398543	1	0.140	0.147
604657	5	0.088	0.113
23933	2	0.020	0.020
427389	6	0.007	0.021
376845	1	0.030	0.044
602577	9	0.060	0.060
352437	2	0.025	0.028
402554	3	0.015	0.044
402554	9	0.020	0.025
373259	1	0.014	0.0143
13533	1	0.040	0.050
377898	3	0.083	0.117
723713	1	0.178	0.148
700379	1	0.100	0.130
708267	2	0.040	0.028
419265	3	0.149	0.166
608629	3	0.070	0.059
38691	2	0.200	0.205
341717	1	0.102	0.167
20761	1	0.166	0.156
435215	6	0.034	0.045
334356	20	0.160	0.174
427290	2	0.112	0.114

FIG. 49.—Comparison of old and new time values for sawing asbestos lumber.

all very similar. The check should cover at least 30 or 40 jobs and more if practicable. Greater confidence will be engendered in the minds of those to whom the formula is later to be sold if they are shown a representative list of jobs upon which a check has been made.

Time values which have been established by estimates or overall checks should not be used in testing a formula unless they are considered only for what they are worth. Such values are practically certain to be very inconsistent. If such a value does not check with a formula value, it is quite natural and logical to assume that the old value is incorrect. To be perfectly consistent, any agreement which may be found between old and new values must be attributed mostly to chance. It is better, when only such values are available, to make the test by the third or overall check method.

Checking Where No Accurate Time Values Exist.—In some cases an insufficient number of time values upon which dependance may be placed will be available. It is then necessary for the time-study man to establish time values of his own which will be used solely for the purpose of making the check. He already has on hand the detail time studies from which he constructed the formula. A check of time values worked up from these studies against values set on the same jobs by the formula will tell whether or not the time-study man has compiled his formula correctly from his available data. It will not, however, tell whether or not the formula is truly representative. There is a chance that the jobs on which the formula is based were not strictly representative, and this is one of the things which the test must determine.

The time-study man must, therefore, establish additional time values on jobs which were not used in constructing the formula. It is not essential that these time values which will be used only for checking be established from detail time studies. Detail time studies, of course, will give highly accurate time values, but the accuracy needed for a check does not warrant the amount of time and labor involved. Rather, it is only necessary in most cases for the time-study man to observe one piece being made. He will note the overall time taken, the time for any foreign operations which may have occurred, the skill and effort exhibited by the operator, and the conditions under which he worked.

The overall time less the time taken up by foreign operations multiplied by the leveling factor determined by skill, effort, and conditions, will give the standard time for performing the operation. This time increased by the allowance percentage will give the allowed time which may be used for the purpose of checking the formula. The allowed time thus found will be entirely

accurate enough for the purpose of the check. If any large discrepancy is found between the time established by the overall time check and time computed by formula, a detail time study should be taken to determine which is wrong.

Making Overall Formula Checks.—The making of these overall formula checks may be greatly facilitated by the use of the form shown in Fig. 50. When the check has been made, this form may be filed away with the other data which were used in constructing the formula. The first seven columns are filled in when the check is being taken. The subsequent computations may be performed at leisure.

It is possible, in a comparatively short time, to get overall checks on the 30 or 40 different jobs that are needed for an accurate test, provided that such jobs are being worked at the time. If not, the time-study man will have to watch the floor and take his checks whenever he sees a job being worked on which he has no data. He may, if he wishes, rule up the back of the form so that he can conveniently record thereon the variable characteristics of the particular jobs he is checking. Such a ruling designed to check a formula is shown in Fig. 51. More will be said later about special forms which make easy the collecting of the information necessary for establishing time values by formula.

When the time-study man has collected sufficient data, it is a simple matter to make a comparison. The formula values will be found by substituting properly in the formula. The allowed time may be conveniently computed from the equation:

$$\text{Allowed time} = NLA$$

where A = (per cent allowance + 100) ÷ 100,
L = leveling factor,
N = net overall time.

Results of the Test.—After the values for making the test have been obtained, the next step is thoroughly to analyze them. If the formula values check closely with the values against which they are being checked, it is necessary only to make certain that at least one of each type of job which will come under the limits of the formula is included in the check. If this is found to be the case, the formula may be considered as definitely correct.

If the formula values do not check with the other time values, it is an indication that further analysis is necessary. If the

Drawing	Item	Overall time	Foreign operations	Skill	Effort	Conditions	Net overall time	Leveling factor	Standard time	Per cent allowance	Allowed time

FIG. 50.—Form used for making an overall formula check.

Pattern number	Number per box	Volume	Strike area	Box area	Base area	Number per plate	Black	Description

FIG. 51.—Form used for collecting variable job characteristics when checking a formula.

formula has been checked against existing time values, it may be felt that the formula is right and that the other values are wrong. Any question of the accuracy of these time values may be settled by making a test by the overall check method. If this test shows the formula to be correct, it may safely be assumed that the existing time values were wrong. Where certain time values check with formula values and others do not, it will probably be found that the formula applies to certain classes of work and not to others. The formula should be revamped so that it will apply to all cases, or its application should be limited and a new formula made to cover the other work. If no agreement at all is shown by the check, the formula must be gone over carefully and checked for errors. In the majority of cases, however, if the formula has been compiled according to the methods given in the preceding chapters, it will be found to check out satisfactorily.

Importance of Selling the Formula.—Once the time-study man has firmly convinced himself of the accuracy of the formula, his next step is to convince everyone else who will come in contact with it that with it time values may be established as well as or better than by time study. This step is particularly important where the idea of the formula is new. It is difficult for anyone not acquainted with the details of formula construction to see how the time-study man expects to establish accurate time values without taking time studies and without, in most cases, even watching the job being done. The impression is likely to be conveyed that time values so given are merely estimates. The workers will often at first complain that the values are too low, thinking that the time-study man has nothing to back up his work. They have little trouble in convincing uninformed foremen that the time-study man is establishing values by guesswork and that his guesses are all too low.

Rather than have this feeling become prevalent, it is better to sell the formula before it is put into actual use. Even in plants where formulas have been used for years, it is well to go over at least briefly every new formula with all who may be interested. Any renascent doubts as to the fairness of formulas will thus be nipped in the bud.

Selling Formulas to the Supervisors.—The first man to convince of the fairness and accuracy of formulas is the plant manager. It will, of course, be necessary to have his backing

before going ahead. He will be interested not so much in any one formula in particular but rather in formula principles and practices in general. A brief outline of the principles given in the foregoing chapters together with a simple formula as an illustration should be enough to convince the manager of the soundness of formula practice. Once convinced, there will be little need of reopening the subject with him.

The superintendent of the department in which the formula is to be used should have the subject of formulas presented to him in the same general way, with perhaps a little more detailed explanation of the formula itself. If the subject is presented to him properly, he will readily see the reasoning behind the formula. He will recognize that certain elemental operations must be performed every time a piece is made and that they will be constant. He will readily see that the deeper a certain sized hole is drilled in cast iron, the longer it will take and that it will require longer to drill a given hole in steel than it will in brass. Such variable relations he will recognize as fast as they are pointed out to him, and in the end he will be convinced that a formula is merely applied common sense. The mathematics involved in formula expression will appear as a mere detail after a thorough explanation of principles, whereas if he were to be presented the formula without the explanation, he would feel that it was all theory and mathematics and of questionable value in everyday work.

The foreman who supervises the work which the formula covers should next be shown the formula. After he understands the principles involved, he will be interested in quantitative details, such as how much time is allowed for performing a certain operation and how another operation is handled. The time-study man will demonstrate, with the list of representative jobs used to test the formula, the accuracy and consistency of the formula. He will call attention to the fact that, as the job characteristics which affect the time vary, the time allowed varies in a proper proportion.

Selling Formulas to the Workers.—It is seldom practicable to give such a complete explanation of formulas to every worker who is to work under them, although the time-study man is always ready to go into it with any who may be interested. Rather it is a case of selling the time values themselves. If the worker is convinced that he can meet or better a number of

time values and that all other values will be set in the same way, he will not question the method by which they are set. The longer he works under such time values, the more he comes to appreciate their accuracy and consistency. The vast fair-minded majority of workers will not question any time values unless a question is justified because of some clerical error in computing one particular time-value. Thus it may be seen that formulas, once proved correct, bring about better feeling between time-study men and workers and decrease the number of complaints and arguments both justifiable and unjustifiable.

CHAPTER XXIV

THE FORMULA REPORT

After the formula has been compiled and tested, there remains only the writing of the formula report before it may be considered completed. The formula may be used by the time-study man who made it or by others under his personal supervision before the report is written. This is not, however, the best practice. Once the formula has been put in use, there will be so many details arising to claim the attention of the time-study man that he will have little time for a week or more to work on the report. When he has time, he will probably be wanted badly elsewhere, and he will tend to let the report go for a still longer time. When he finally does get to it, the details of the formula are no longer fresh in his mind, and the report suffers accordingly. Therefore, if possible, the report should be written as soon as the actual formula is completed.

What the Report Is.—The formula report tells in full all the details of the construction of the formula, and it also gives a clear account of just how the formula is to be applied. A good formula report should make two things possible. First, it should enable anyone to check back at any future period and see where and how each value was obtained. The element analysis will show the reasoning process followed by the time-study man in dealing with each individual elemental operation. The formula report will show just how these values were combined and built up into the final formula and will also enable one to trace back to the original study from which each value was taken. Second, the formula report will make it possible for anyone who is familiar with formulas in general to apply the particular formula even though he has never seen it before. The importance of the report should now be clearly apparent. In order that the report may do all that it should do, it must be written in a clear manner, and it should overlook no detail connected with the formula. A good report is not easy to write, but any time spent to make it per-

fectly clear will pay for itself time and again. The time-study man who made the formula will not always be available for questioning, and when he is not, the formula report must furnish all the information required.

Now and then some workman gets the idea that he is doing something on the job which has not been considered in the time allowed. If he is right, the formula should be revised to take care of it, but if it has already been taken care of, the formula report should show conclusively that this is the case and also just how much time is allowed on any particular job. As an example, on the operation of winding revolving field coils, it was necessary to replace empty wire reels with full ones, the size of the coil being wound determining the number which could be made from each reel. The time required to change reels complete was found to be 0.1400 hour. Upon checking a number of reels it was found that the average weight was 100 pounds. It was decided to include time for this work with the time for winding the coil. This was done by dividing the time taken to change reels by the average weight of a reel of wire, which gave the time to change reels per pound of wire as $\frac{0.1400}{100}$ or 0.0014 hour. Then to each coil was added the time to change reel per pound of wire times the number of pounds the coil weighed, which would be in the case of a 20-pound coil 20×0.0014, or 0.028 hour. One of the operators who was engaged on this work did not understand how this was taken care of and questioned his foreman. The foreman took the matter up with the time-study man who secured a copy of the formula report which very completely and comprehensively explained how this time was added. The evidence was there and could not be disputed. The operator and foreman were fully satisfied and were sold to the formula method of establishing allowances. If the formula report had not been complete in this respect, it might have been difficult to convince these men and might have aroused their suspicions as to the honesty of purpose.

Report Outline.—The formula report should be written up in standard form both to insure a uniformity of practice throughout the plant and, more important, to minimize the chance of the omission of any pertinent facts. The standard subdivisions which should be used in all reports are as follows:

Formula Number
Date

Part:
Operation:
Work Station:
Allowed Time:
Application:
Analysis:
Procedure:
Time Studies:
Table of Detail Operations:
Synthesis:
Inspection:
Payment:

In addition to these standard subdivisions, any other set of facts which it is desirable to keep apart may be placed in separate subdivision with an appropriate subheading. At the end of the report, space should be left for the signature of the time-study man who made the formula and for the approval signature of his immediate superior.

Formula Number and Date.—Every formula should be assigned a number by the man in charge of time-study work in the department where the formula is to be used. The formulas may be numbered from one on up in the order in which they are compiled. This number will serve to identify the formula definitely and it will also give a convenient filing index.

In large plants, it is well also to identify the formula with the department to which it belongs. Thus Formula *A*-10 No. 3 would identify the formula as being the third which was applied in department *A*-10. Such identification practically eliminates the chance for duplicate formula numbers in different parts of the plant.

The date is, of course, the date upon which the formula is first applied. It is extremely important to have this date recorded, for it enables one to check back and definitely determine just what conditions were at the time the formula was made. If any objection to time values is raised on the grounds of changed conditions, it will thus be easy to determine whether or not the objection is valid.

Part.—Under the subheading of Part should be listed the general classes of parts to which the formula will apply. This may generally be expressed in a few words as "all small alloy

and cast-iron castings," or "slate panels up to size 22 by 48 by 1 inches. Wherever the formula applies to a line of work which is identified by type, style, or other numbers or letters, this nomenclature may be used with a gain in conciseness. "Type *AP* and *AF* autostarters," or "801 switch groups," clearly identifies the parts to which the formula applies.

Operation.—The operation which the formula covers is noted under this subheading. This again may usually be expressed in a word or two as "mill," "assemble panel to cabinet," or "cut off to length." Where the formula is more comprehensive and covers a number of different operations performed by one operator or group of operators, every operation included in the formula should be listed for the sake of clearness.

Work Station.—The work station at which the operation is performed should be designated here. If the work is done on a bench or the floor of the shop without the use of machine equipment, "bench" or "floor" describe the work station sufficiently. Where machines are used, a complete description of each machine covered by the formula should be given. The size, type, maker's name, and other identifying information should be fully listed. If the plant assigns numbers of its own to the machine, these should also be recorded. Such complete descriptions will eliminate much future argument when the time-study department revises its formulas because of new and improved machine equipment. There will be no doubt that the revision is due to a change in equipment and not due to an arbitrary cutting of time values.

Allowed Time.—Under this subheading are given the algebraic formulas for computing first-piece and additional-piece times, together with a key to the symbols used. All tables used in connection with the formula are included here. In short, all the information necessary for computing time values when one is familiar with the principle of the formula is given under Allowed Time. It contains the real meat of the formula report. Some examples of the form in which the allowed-time information should be recorded are given in the formula examples in Chaps. XXVII to XXXIII.

Application.—A clear concise statement of the work to which the formula applies should be given under the subheading of Application. If words are chosen carefully, it is generally possible to state the formula application in a single sentence. The following is an example of the manner in which it should be recorded:

This formula applies to the molding of all alloy castings on Tabor Vibrator Molding Machines, Company Nos. 6208 to 6217 inclusive, as done in the brass foundry at the present time with the present auxiliary equipment, sand, metal, and other conditions being as of May 1, 1925.

It will be seen that the first part of the above application is merely a repetition of what has already been stated under Part, Operation, and Work Station. The second part definitely limits the formula to the conditions which were in effect at the time the formula was compiled. The time-study department goes on record saying that the formula will hold good as long as conditions remain unchanged, and the workers are given this additional assurance that time values will not be reduced to limit earnings. At the same time, the time-study department retains the right to change the formula when conditions change, which is but just. The workmen, of course, know that only the time values which are affected by the changed conditions will be adjusted, and they are rightly certain that a minor change in conditions will not be used as an excuse to revise the whole formula.

If the formula applies only to certain sizes of work within a given class, it should be clearly noted under Application. This will serve to inform whoever may be applying the formula of its particular limits of application.

Analysis.—Under Analysis should be told the complete story of the formula. Any point which may need stressing or amplification should be brought out here and everything which has a bearing on the final formula should be explained.

First, a list of the small tools and equipment other than the actual machine should be given. This will include such things as wrenches, pliers, screwdrivers, clamps, dogs, chucks, center punches, brushes, gages and measuring tools of all kinds, surface plates, jigs, fixtures, and any other equipment which may be required to perform the operation.

Next should come a list of the supply materials required, if any are needed. Under this heading would come tape, cotter pins, nuts and bolts, wood screws, escutcheon pins, cutting oil, waste, solder, and other miscellaneous supply material. Such material is generally used on assembly or partial-assembly operations.

A brief but complete outline of the material-handling situation should be given under Analysis. Whether or not material is

handled by special laborers should be noted in order to justify the way handling time was cared for in the formula. If supply men are added or removed at some later date, the time-study department needs to have something definitely recorded about past material-handling conditions, so that it will be able to justify any change in time values which it may be necessary to make. Under this head should be included a description of material-handling equipment such as jib cranes, lift trucks, and the like.

Then should follow a description of how a job is given to the workers and what they must do in the way of getting drawings, tools, supplies, and information before they can start to work. This paragraph will contain a word about any unusual elemental operations, which have been included in the first-piece time. It will also explain just how the time spent in gaging, checking, and finding dial positions on the first piece is allowed for.

Another paragraph under Analysis should give an account of how finished work is counted and checked and how the worker is allowed time for the work he has done. This will include mention of any unusual features in the work of the payroll clerks.

All allowances which have been added to standard-time values should be carefully explained. The ordinary allowances for personal needs, unavoidable delays, and fatigue should be mentioned quantitatively with little or no elaboration. All special allowances should be explained in detail. The reasons, method of determination, and numerical value should be stated clearly and the items which they are to cover should be so given as to minimize the possibility of ambiguity. This point is very important, for both workers and foremen are quick to point out any necessary elemental operations which they feel have not been covered in the formula. Unless all operations that were included in the special allowances are carefully noted, it is quite possible that the same allowance will be added again at some later date.

Other paragraphs under Analysis may be devoted to any additional points which come up in the particular formula being written up. Any unusual features which may come up in doing the work are here discussed. Wherever a word or two of explanation will serve to clarify the formula expression and make the procedure for applying the formula more easily grasped, it should be given. The willingness of the time-study department

to help and cooperate with the workmen may be reflected in suggestions and remarks on how it will be possible to save time by combining trips to the tool or drawing rooms and other similar ways. Not only will this assist the worker to increase his earnings by planning his work, but it will also help to secure greater production from a given equipment.

The time-study man should not try to complete his writeup of Analysis in one sitting. He should record all the points that he can think of when he starts, but he will very probably find that other points continually occur to him as he is writing the rest of the report. These he should add until he can think of no more. A good plan then is to show the rough report to a fellow time-study man and to ask his opinion of it. The questions that this man will ask will quickly show where the report is lacking in clearness and detail. Points that may seem obvious to the man who has worked with the formula from the start will be questioned, and the writer will thus find where addition or elaboration is necessary.

Procedure.—The manner in which the complete operation is performed should be given in outline form. It will be little more than the names of the elemental operations strung together in the order in which they are performed. Operations which are done only occasionally when necessary on a particular class of work should be so marked. The whole purpose of this subdivision is to give one a concise word picture of what the operator must do to perform the operation completely.

Time Studies.—Under this subheading should be given a list of the time studies which were used to compile the Master Table of Detail Time Studies. Three headings may be made as follows:

Study Number	Date Taken	Taken by

In the first column should be noted the numbers which were assigned to the studies as they were placed on the Master Table as *S*-1, *S*-2, and so on. The date on which the study was taken is recorded in the second column and the initials of the time-study man who took the study in the last. This list of studies will be useful in checking back from the formula to the original studies at any future period. It also gives an idea of who made the studies and when.

Table of Detail Operations.—Here is recorded the information which is contained in the first four columns on the Master Table.

The Table of Detail Operations should be headed up as follows:

Symbol	Operation Description	Allowed Time	Reference

This table gives a complete list of all of the elemental-time values which were used in constructing the formula. It will be valuable for reference when anyone questions how much time was allowed for a certain operation. In the Reference column are shown the numbers of the studies as they appear on the Master Table from which the allowed-time values were selected.

Synthesis.—The Synthesis subdivision, as its name implies, shows how the formula for allowed time was built up from the data given in the Table of Detail Operations. First, it shows what elemental operations were combined to form constants. This is clearly denoted by algebraic expressions. The letters which are used in these expressions correspond to the letters in the Symbol column in the Table of Detail Operations. The expression is given first in purely algebraic form as so many A's plus so many B's and so on; next is shown the substitution of the numerical time values; and finally is given the summation of these values or the constant which will be used in the formula expression. The synthesis of each constant used both in the first piece and in the additional piece expression is thus shown in detail.

Under Synthesis, the derivation of all curves is also given. Each curve is discussed separately in detail, and the relation between time and the variable characteristic is gone into. Any synthesis of the curves themselves is also shown, as are all derivations of algebraic expressions from curves. Any information which will show how tables of computed values were compiled should be included under this head.

Inspection.—The inspection standards that are in vogue at the time the formula was made should be recorded under this heading. Inspection requirements are no more fixed than many other things which affect the amount of work which must be done. If the requirements are made more rigid sometime after the formula has gone into effect, it is only fair to the workman to allow him more time, if more time is required to produce a better job. The time-study man will wish to know what the standards were when the formula was made in order that he may be certain of how much has already been allowed for. If, on the other hand, it is decided that a less carefully made job will be satisfactory or that a smooth surface with no tool marks is not necessary, then the company

will be entitled to the saving thus effected. Here again the former requirements must be known in order that the time-study man may make the adjustment fairly and to the satisfaction of all.

The inspection requirements may be learned from the inspection department. If written inspection standards are available the time-study man is safe in incorporating them under the Inspection subdivision. If not, the time-study man must ascertain the requirements by questioning the inspector. He must be very careful not to take any answers which are given offhand, and he should satisfy himself that the inspector will actually require all that he says he will. The time-study man, of course, investigates the inspection requirements before he takes any time studies, as was explained in the early part of this book.

Payment.—The name of the wage-payment plan under which formula values will be applied should be given in this subdivision. If it is the standard system which is used in the plant as a whole, merely the name need be given. If some special system designed to meet special conditions is to be used, a complete explanation of the workings of the plan should be made.

Special Subdivisions.—Any important features of the formula report which do not properly fall in any of the above standard subdivisions may be handled separately and specially. Where a certain line of work is divided and classified as small, medium, or large, simple, medium, or complex, or according to some other method, a special subdivision defining exactly what is meant by each of these terms is practically essential to the correct application of the formula. Several examples of special subdivisions will be noticed in the examples of formula reports which are to follow.

Signatures.—Every formula report should be signed in ink by the time-study man who made it. It should also bear the signature of the time-study supervisor. The title Time-study Supervisor is used to denote the immediate superior of the time-study man. His actual title will vary with the plant with which he is connected. The typing in the space for signature should be in the following form:

Approved:

______________________	______________________
Time-study Supervisor	Time-study Department

These signatures should come at the end of the formula report.

Formula Working Sheets.—The routine time-study man who is to apply the formula does not need to refer in his daily work

Formula P-2 No. 26.
Nov. 15, 1925.

Part:
Controller shafts.
Operation:
Grind gear, handle, star wheel, and bearing fits.
Machine:
Norton grinder, size 6 by 32 inches (2-inch stone) No. 23793.
Standard Time:
First-piece Time.—0.163 + T + 3 (each additional-piece time).
Additional-piece Time.—$0.0175X + 0.0016L_s + 0.0134Y + 0.0087(L_t - 1) + 0.0021$

where L_s = total length in inches of fits $1\frac{7}{8}$ inches or under.
L_t = Total length in inches of fits over $1\frac{7}{8}$ inches.
T = values from Table I.
X = number of fits $1\frac{7}{8}$ inches or under.
Y = number of fits over $1\frac{7}{8}$ inches.

TABLE I.—TRUE STONE

Number of Fits per Shaft	Decimal Hours
1	0.1068
2	0.1068
3	0.1602
4	0.2136
5	0.2670

Application:
This formula applies to rough and finish grinding of shafts up to and including 6 pounds where length of fit does not exceed 8 inches, as done in Sec. P-2 with methods and equipment as at present.
Inspection:
Inspected for size. Inspection requirements are:

Handle, star wheel, and gear fits.............. $\begin{cases} +0.0005 \\ -0.0000 \end{cases}$

Bearing fits............................... $\begin{cases} -0.0010 \\ +0.0000 \end{cases}$

Payment:
Standard-time job basis.

Approved: A. W. Grear, Time-study Supervisor; Jas. C. Carter, Time-study Department

FIG. 52.—Example of formula working sheet.

to all of the subdivisions included in the formula report once he has become familiar with what is contained therein. He will use chiefly the material contained under Allowed Time although there

are several other items which he should have before him. He is very likely to be using more than one formula, so in order to cut down the bulk of paper and in order to make it more convenient to handle the formulas, formula working sheets should be made which will contain only the information which is needed to carry on the daily work of setting time values. These working sheets should include the formula number and date; part, operation, work station, allowed time, application, inspection, and payment subdivisions; signatures; and all tables, curves and charts.

The formula working sheets may be typed up in the manner shown in Fig. 52 on thin paper, and for the sake of the appearance, within the bounds of a heavy border. From these sheets blueprints may be made which will be the working sheets used by the routine time-study man. By the use of blueprints, the replacement of dirty or torn working sheets becomes a comparatively inexpensive matter. The typewritten formula report may be kept in a clean place, and since it is handled infrequently, will remain legible for a number of years.

The working sheets of all the formulas used by one time-study man may be kept together arranged in numerical order in a clamp cover. From this one book, the time-study man will then be able to set time values on all of the work which he handles. He will always keep his formula reports filed conveniently, so that he may readily check back on any point of formula construction and show definitely how every point was cared for.

CHAPTER XXV

CLERICAL ROUTINE

When the formula report has been finished, the formula, as far as the time-study man is concerned, is complete. There remains, however, a certain amount of clerical work necessary to put the formula and all the paper work connected with it into the best permanent form for use and reference. If this is not done systematically, part of the data or computations or rough curves will very probably soon become mislaid, and any rechecking or revising of the formula will become increasingly difficult as time goes on. Anyone who has tried to piece together the details of the construction of an old formula from a few scattered time studies and some unidentified computations will readily recognize that time spent in putting such information into shape for reference is time well spent indeed.

Stenographic Work.—The formula report and the formula working sheets should be typewritten in order to have them in neat legible shape. At least three copies of the formula report should be made and more, if more than one routine man is to apply the formula. Only one copy of the working sheets is made, and duplicates are obtained by blueprinting.

Unless the time-study man can do exceptionably good freehand lettering, typewritten scales, titles, and the like on all curve sheets promote neatness and uniformity of appearance. Most tables may be typewritten to advantage except where more compactness than is possible with a typewriter is desired.

Working Data.—All the data which were used in making the formula should be gathered together and kept on hand for reference. This may be done conveniently by placing all such data in a paper envelope about 9 by 11½ inches in size. Such an envelope will be practically dustproof, and it will hold very nicely all the miscellaneous sizes and shapes of paper upon which various pieces of information may have been recorded. For purposes of identification and filing, number, part, operation, and date of the formula should be marked on the upper right-hand

corner of the envelope. Figure 53 shows a form in which this information may be arranged. A rubber stamp may be used to mark this form on the envelope. Where more than one envelope is needed to hold the working data, the total number of envelopes used should be marked on each envelope. One may thus always be sure as to whether or not he has a complete set of data.

FORMULA........................
PART............................
OPERATION......................
DATE.............................

FIG. 53.—Form used for formula identification purposes.

An itemized list of what should be placed in the envelope is as follows:

All time studies.
Master Table of Detail Time Studies.
Element analysis.
All rough curves and computations.
Sketches.
Pencil copy of formula report.
Formula test data.
Extra copies (at least one) of formula report.
Extra blueprinted working sheets.
Miscellaneous data bearing on formula.

Related data should be clipped together and marked. The contents of the envelope will in the majority of cases subdivide itself into the groups given in the above list. If these groups are kept separate and are properly marked, much subsequent hunting will be eliminated.

Central File.—The original typed formula report and the typed formula working sheets should be placed together in a white manila folder. The formula identification form may be stamped on the folder with the rubber stamp previously mentioned. This folder should be kept in a central file in the office of the head of the whole time-study organization. There will be less chance of this information becoming soiled or lost in a file of this sort than there is in the less permanent files out in the shop offices. In addition, all formulas come under the inspec-

tion of one man. Knowing what has been done towards formulating data on a certain class of work in one department, he will be in a position to prevent any duplication of effort in other departments. He will be able to supervise formula work in general and will know whether or not standard practice is being followed. If he comes across a good new idea developed by one time-study man, he will quickly pass it on to all other time-study men.

When new blueprint copies of formula working sheets are needed, it is necessary merely to call the central file and request that they be made. If these sheets were kept by the individual time-study men or even by the time-study supervisors, the chance for certain sheets becoming mislaid or lost is readily apparent.

Establishing Time Values by Formula.—The routine work of establishing time values by formula should be carefully considered, for any work which may be saved will be multiplied by many time values. The routine will vary with the nature of the work and the nature of the formula. It has, in general, five main steps; jobs upon which no time values have been set must be brought to the attention of the time-study man; the time-study man must collect the information necessary for applying the formula; he must compute the time value; he must tell the worker what the time value is to be; and he must make a permanent record of the time value so that he will not have to compute it every time the job comes along.

Ascertaining What Jobs Have No Time Values.—A workman likes to know what the allowed time is before he starts in on a job. Not only that, but he is likely to withold his best efforts until he learns what the time value is, thinking that the time-study man may be influenced by what he does. An explanation of the way time values are set will serve to minimize this feeling, but it exists to quite an extent in a number of cases. Both in order to satisfy the workman and in order to speed up production, it is desirable, if possible, to establish time values before the job is worked. Whether or not this is possible and how it may best be done are dependent upon the nature of the formula and the particular dispatching system used for starting jobs through the shop.

With certain machine formulas, it is necessary to see the job made and to get the actual cutting time taken. This is, however, generally due to the fact that insufficient data on feeds and speeds are available, and comprehensive data will eliminate the necessity

for timing such jobs. Where such formulas are in use, it is obviously impossible to establish a time value before the job is started. In cases like this, the worker notifies the time-study man when he is ready to start the job. The time-study man goes out on the floor and gets his data as soon thereafter as he has a little spare time.

Most formulas permit the establishment of time values either from the drawing or from the piece being worked. Where it is possible to use drawings, the workmen bring them to the time-study man whenever they get them where no definite dispatching system is used. Attached to the drawing is the time slip of the worker. When the time-study man has computed the time value, he notes it on the time slip. The workman gets the drawing and the time slip on his next trip to the office. By getting drawings and time slips ready as soon as he knows that he is to do a certain job, the worker will be able to obtain the time value before he is ready to do the actual work.

When work is given out at a central dispatching station, the time-study man can periodically examine the jobs which are to be made and can easily have the time values set before they are due to be worked.

Collecting Information.—The time-study man must get together certain information before he computes time values from his formulas. Where he can obtain this information from a drawing at his desk, he can look up each variable when he is ready to use it. When, however, he must go out onto the floor or to the dispatching station and examine the job itself, he must record all necessary information in such form that he can use it later at his desk. He will find it very useful to draw up some sort of special form which will enable him to record the information in an understandable manner, to be sure that he has recorded all that he will need, and to place the information in convenient form for substitution in the formula.

An example of such a form is given in Figs. 54 and 55. This form is used with a sensitive drill press formula. It is necessary to go out on the floor to examine the nature of the drill jig when one is used. The other data may be obtained from the drawing of the part, but the form will facilitate recording them and computing the final time value.

Considerable ingenuity may be exercised in devising such forms. If the routine man has the inventiveness and vision necessary for

compiling formulas, he will reflect it by devising such labor-saving forms. Any tendency in this direction will be heartily

Size Material	Jig Vise Table	AVEY DRILL PRESS Operation			Item Sub.	Drawing	
E	No. spindles not tapping			K	No. of blind holes		
F	No. spindles tapping				Constant		
G	No. drills over ⅝" diameter						
A	No. of clamps			R	No. parts turned in vise		
B	No. jigs blown out-turn over			S	No. holes same size minus		
B-1	No. jigs cleaned with brush			T	No. thumb nuts		
C	No. covers opened and closed			U	No. times jig is turned over		
C-1	No. covers put on and taken off				Constant		
H	No. of hexagon nuts				Miscellaneous values		
I	No. times bushing is inserted				How handled		
L	No. locater screws—hand						
L-1	No. locater screws—wrench				First Piece		
M	No. spindles				Each Additional Piece		
P	No. of parts in jig or vise						

Fig. 54.—Face of form used for recording job characteristics to facilitate establishing time values on Avey sensitive drill press work.

Drill Size	Depth Drilled	Value From Table	No. of Holes	Allowed Time	Tap Size	Depth Tapped	Speed	No. of Holes	Thds. Per In.	Allowed Time
					Countersink					
					Redrill					
					Ream					
					Formula F-1 #12					
Note:	If counter-bored, mark CT.				Date					

Fig. 55.—Back of form shown in Fig. 54.

encouraged by the time-study supervisor who is continually on the lookout for men who have the necessary caliber to become time-study experts.

Computing the Time Value.—Computing the time value is theoretically merely a matter of substituting certain quantities in an algebraic expression and determining the result, but here,

Size Medium Material Alloy #6	Jig	AVEY DRILL PRESS Operation Drill, Burr, and Tap		Item 1 Sub. 6	Drawing 721906		
E	No. spindles not tapping	5	.2090	K	No. of blind holes	1	.0192
F	No. spindles tapping	1	.0683		Constant		.2928
G	No. drills over ⅝" diameter	—					
A	No. of clamps	—		R	No. parts turned in vise	—	
B	No. jigs blown out-turn over	1	.0014	S	No. holes same size minus 1	14	.0196
B-1	No. jigs cleaned with brush	—		T	No. thumb nuts	3	.0036
C	No. covers opened and closed	1	.0006	U	No. times jig is turned over	5	.0060
C-1	No. covers put on and taken off	—			Constant	—	
H	No. of hexagon nuts	—			Miscellaneous values	—	
I	No. times bushing is inserted	3	.0030		How handled	—	
L	No. locater screws—hand	2	.0062				
L-1	No. locater screws—wrench	—			First Piece		.679
M	No. spindles	6	.0108		Each Additional Piece		.090
P	No. of parts in jig or vise	1	.0040				

FIG. 56.—Face of form shown in Fig. 54 filled in.

Drill Size	Depth Drilled	Value From Table	No. of Holes	Allowed Time	Tap Size	Depth Tapped	Speed	No. of Holes	Thds. Per In.	Allowed Time
13/32	5/8	.0014	4	.0056	24	3/8	950	4	24	.0028
17/32	3/4	.0018	4	.0072						
25/64	1	.0021	3	.0063						
242	5/8	.0011	4	.0044						
					Countersink					
					Redrill					
					Ream					
					12 Holes Burred .0084					
					Formula F-1 #12					
Note:	If counter-bored, mark CT.				Date 6-5-26					

FIG. 57.—Back of form shown in Fig. 54 filled in.

again, much ingenuity may be shown. The man who is applying the formula will find that certain conditions occur frequently, and he will be able to save himself time by making up tables and

lists of figures which will cover these conditions. Time-saving devices that the man who compiled the formula would be unlikely to see should be readily apparent to the man who works daily at applying the formula.

The computation of sensitive drill press time values is made easy by use of the form mentioned above. When the variables have been noted, it is necessary only to multiply the proper values by the number of occurrences, record the products, and add them up. The way the form looks after the value has been computed is shown in Figs. 56 and 57. From this one example, the amount of time that may be saved in the computing of time values by making special forms should readily be apparent. The formula must, of course, be sufficiently active so that the time saved will offset the cost of the forms.

Informing the Worker of the Allowed Time.—The manner in which the worker learns the allowed time will depend on particular conditions. Where he has left a time slip attached to the drawing on the desk of the time-study man, he will find the allowed time thereon recorded when he again gets it. If the time-study man has figured time values on jobs which are still in the dispatching station, he will note the allowed time on some convenient space on the paper work that goes with the job. When it has been necessary to see the job actually worked, the time-study man should make a trip out to the worker and tell him the allowed time as soon as he has it computed.

In any case, the manner of telling is not so important as the fact that the worker should be told. If there is any complaint about a time value, it is better to have it while the job is still being worked. Then, in extreme cases, it is possible to take a detail time study to prove whether or not the value is correct. Otherwise, the best that the time-study man can do is to promise to study the job the next time it comes along, which is satisfactory neither to him nor to the worker.

Permanently Recording Allowed Time.—The allowed time, once established, should be permanently recorded. The routine by which this is done has already been discussed in Chap. IV.

CHAPTER XXVI

FORMULA-REVISION PROCEDURE

There should be a fixed procedure for revising a formula as well as for making the original, for it is just as desirable that the revised product be in standard form as any other formula. The procedure for revising a formula parallels closely that for compilation, although a revision is generally a much simpler task.

Reasons for Revision.—Formulas must be revised because conditions in modern industry do not remain the same year after year, but change with more or less rapidity. Any change which will affect the time for doing the formulated operation is cause enough for formula revision. Before any change is permanently put into effect, it should be certain that it is for the best and not just a remedy for a temporary condition. The revision of a formula and all established time values involves no little expense and should not be made unless there is something to be gained.

Some changes which will necessitate the revision of a formula are the installation of better machine equipment, a radical development in jigs, fixtures, or special hand tools, the introduction of improved cutting tools which will work under heavier speeds and feeds, a change in material-handling conditions, a better method for performing the operation or a change in inspection requirements. It is rather obvious that changes of the above nature will cause a change in the time required to do the work. In fairness to the company when the time is lowered and to the workmen when the time is raised, the formula must be changed.

Collecting Data.—Before the change is made, the time-study man should become familiar with the details of the old formula. He should study in particular the element analysis to learn how each elemental operation is performed. Then when the change is made, he will be in a position to see just what elemental operations are affected. Knowing this, he will make time studies for the purpose of determining the new time on the changed elements.

All elements but those affected may be combined in these studies into as few long operations as is convenient in order to save labor in taking and working up the data. Enough studies should be taken to fix definitely the new time allowed on the changed elements.

Working Up Data.—The general method of working up the data is exactly the same as that used in compiling an original formula. Elements are classified as constant or variable and the time allowed determined accordingly.

Outline of Revised Formula Report.—When the revised formula expression has been completed, it is necessary to revise also the formula report. The report should show the reasons for and the nature of any changes that have been made. The outline of the subdivisions of the revised report is as follows:

Formula Number
Revision Number
Date Revised

Part:
Operation:
Old Work Station:
New Work Station:
Old Allowed Time:
New Allowed Time:
Old Application:
New Application:
Reasons for Revision:
Analysis:
Procedure:
Time Studies:
Additional Time Studies:
Old Table of Detail Operations:
Table of Changed Detail Operations:
Synthesis:
Inspection:
Payment:
Signatures:

The subdivisions which have the same headings as those in the original report remain unchanged. The changed paragraphs will be discussed separately in detail.

Revision Number.—The number of the revision should appear directly under the formula number. This will aid in identifying the report. The date upon which the revised formula is to be first applied is the only date that need be given.

Old Work Station—New Work Station.—The distinction between the old and the new work stations need only be made if the work station has been changed. If it has not, this subdivision should be headed Work Station and the description given should be identical with that of the original report.

A change in work station means, in the majority of cases, a change in machine equipment. Occasionally a bench or special floor fixtures may be devised to replace standard equipment. Such a change would be a change in work station, but they are not often encountered. Under Old Work Station should be given the description which appeared in the original report under Work Station. The description of the new equipment will be given under New Work Station.

Old Allowed Time—New Allowed Time.—These headings are self-explanatory. The old allowed time is given largely for reference purposes. Occasionally it may be necessary to check a time value to see whether it is a new or an old formula value or whether it was set by time study. Substitution in the two formula expressions will settle the doubt. The new allowed time data are those, of course, which are used in establishing time values.

Old Application—New Application.—The headings again explain themselves. The new application shows the conditions under which the revised formula is applicable. The old application is inserted as a reference and to add clearness to the report as a whole.

Reasons for Revision.—Under this heading should be given a clear analysis of the difference between old and new conditions. The way in which changes affect parts of the allowed time should be explained in detail. Any former elemental operations which are rendered unnecessary by the change should be listed. This subdivision is to the revision what Analysis is to the original report. The same items should be taken up and discussed in so far as they have been changed. A clear and logical outline of the line of reasoning followed in making the revision should be set forth, both as a matter of record and as an aid to the making of further revisions.

Additional Time Studies.—The time studies which were taken for the purpose of the revision should be listed in the same manner as the original time studies. A new Master Table of Detail Time Studies was probably compiled, and in order to avoid con-

fusion, its study numbers should be given a subscript as $S\text{-}1_R$, $S\text{-}2_R$, and so on.

Table of Changed Detail Operations.—The work involved in giving an old and a new Table of Detail Operations is considerable, and it is not necessary to do this unless the majority of elemental operations have been changed. In most revisions, only a small percentage are changed, and in such cases, it is more convenient to insert simply a Table of Changed Detail Operations after the old table.

The Table of Changed Detail Operations may, in order to insure clearness, be divided into three parts; Canceled, Revised, and Added Detail Operations. Such a division makes apparent at a glance just what was done in changing the values used in making up the formula expression.

Other Points.—Under Synthesis, any changes which may have been made in the expressions from which constants are obtained should be shown. The best way to show this will vary with the nature of the expression. The explanation of the change need not be elaborate, but it should be clear and easy to follow. Any changes which have been made in curves should also be gone into fully.

If a change in inspection requirements has been the cause of the formula revision, the old and the new standards should be set forth under separate heads. If not, Inspection will be the same as in the original formula report.

If a number of individual operators whose performance was checked and earnings calculated on a day basis were organized into a group, then the group's performance would be checked and earnings calculated on a pay period basis. The change in wage-payment plan would be shown under the Payment subheading.

The revised formula report is signed in the same manner as the original. New working sheets will be made up which will show all changes which come under the work station, allowed time, application, inspection, and payment headings. The subdivision on Reasons for Revision should be included on the working sheets.

Clerical Routine.—Typewritten copies of the revised formula report and of the new working sheets should be made out as before. All blueprinted copies of the old working sheets and all but the original copies, pencil and typewritten, of the original formula report should be destroyed.

All data used in revising the formula should be sorted out, clipped together, and marked in the same way that the original data were handled. They should be filed away in the envelope with the original data.

Nothing should be destroyed from the white folder. The original of the typewritten copy of the revised report and the original typewritten revised working sheets should be filed with the old. The revision number should be placed on the outside of both the envelope and the white folder.

CHAPTER XXVII

FORMULA FOR PANEL MOUNTING

It is the purpose of these next few chapters to give examples of formulas which have been compiled and successfully applied in order to demonstrate clearly the wide range of work which may be covered. In addition, the construction of the formula on panel mounting given in this chapter will be gone into step by step in order to illustrate by an actual example the points brought out in previous chapters.

The formula on mounting panels in enclosing cabinets was selected for two reasons: first, because it covers a simple operation, and hence does not involve a lengthy discussion of the nature of the work and, second, because it illustrates some of the things that a time-study man should not do, as well as those that he should do.

General Analysis and Survey.—The general analysis of the operation of mounting panels in enclosing cabinets showed, among other things, that panels were mounted in several different ways. They were mounted in some cases on mounting studs, and in others they were bolted to mounting brackets within the enclosing cabinet. The holes in the mounting brackets were laid out for drilling, using the panel to be mounted for a template. Still another type of panel was mounted on the outside of a screen-sided box, and the box itself was assembled by the panel mounters.

A further analysis of the work performed showed that there were only two panels of a special type which were mounted on screen-sided boxes. Hence, it was obviously easier to cover this class of work by time study. The rest of the panels were mounted in enclosing cabinets, and hence it was necessary to get representative studies on jobs taking mounting studs, on the laying out for drilling of mounting brackets, and on the mounting of jobs taking mounting brackets.

A general survey of conditions showed them to be good. Sufficient attention had been given to supplying the proper hand tools and miscellaneous materials, such as bolts, rivets, and the like.

The workers had plenty of room to move about, but cabinets and panels were stored fairly close to them.

Collecting and Tabulating Data.—Three jobs using mounting studs and four jobs using mounting brackets were studied both for layout of the mounting brackets and the actual mounting. The jobs covered a wide range of size, but had it not been that nearly all variable operations were unaffected by whether mounting studs or mounting brackets were used, the number of studies taken would have been insufficient. As it was, the number available was just about the minimum for satisfactory results.

When it came to posting the collected data on the Master Table, it was found that a cardinal point had been neglected. The elemental operations had not been subdivided similarly in all studies. The data covered two Master Tables, and there were few elements for which more than two time values occurred. The work covered by the studies was bench work, and in many cases, it was impossible to split up operations in a definite way because the operator himself varied his method of performance. For example, take the case of inserting four bolts into tapped holes. The first time that the operation was performed, it might be divided into "put in one bolt with fingers" and "tighten one bolt with wrench." The next time this operation occurred in another study, the operator might insert one bolt, tighten only partially with a wrench, repeat this three more times, and then go over all four bolts with the wrench to secure them more tightly. Of course, while there is practically no difference in the overall time for inserting each bolt, it is impossible to make the subdivisions of the first case in the second.

The time-study man should have decided how he wanted each operation performed and then should have instructed the operators accordingly. He would have then been able to divide up the operation into its elements uniformly throughout his time studies. In the particular case under consideration, this was not done, and as there were many reasons for completing the formula as quickly as possible, it was necessary to work with the data at hand.

In order to get the data into good shape, it was necessary to make a number of computations. These were all included in the element analysis so that it is possible to check back and determine how any computed value was derived. Thus the element analy-

sis is somewhat more elaborate for this particular formula than it would be had the data been collected properly. It does do, however, what a good element analysis should do; that is, it shows every step made by the time-study man in arriving at the final values to be used in the formula. The element analysis will here be set forth in detail:

ELEMENT ANALYSIS

		Reference
Mounting Studs:		
Data:		
Place 3 mounting studs in box	0.0123	*S*-1
Screw on 1 nut with fingers	0.0075	*S*-1
Tighten 3 mounting studs with screw driver	0.0104	*S*-1
Place 4 mounting studs and nuts loosely	0.0466	*S*-3
Place 4 mounting studs and nuts loosely	0.0599	*S*-5
Tighten 4 studs with screw driver	0.0087	*S*-3
Tighten 4 studs with screw driver	0.0160	*S*-5
(1) Place 3 mounting studs in box and put nuts on loosely = 0.0123 + 0.0225 =	0.0348	
(2) Place 4 mounting studs in box and put nuts on loosely	0.0466	
(3) Place 4 mounting studs in box and put nuts on loosely	0.0599	

Assume a straight-line relation as to time per bolt in (1).

$$\frac{0.0348}{X} = \frac{3}{4}. \quad X = 0.0464 = \text{time for 4 bolts}.$$

Tighten 3 mounting studs with screwdriver	0.0104
Tighten 4 mounting studs with screwdriver	0.0087
Tighten 4 mounting studs with screwdriver	0.0160

Assume same relation for tightening in (1).

$$\frac{0.0104}{X} = \frac{3}{4}. \quad X = 0.0139 = \text{time for tightening 4 bolts.}$$

Overall time for putting in 4 mounting studs complete:

(1) $0.0464 + 0.0139 = 0.0603$

(2) $0.0466 + 0.0087 = 0.0553$

(3) $0.0599 + 0.0160 = 0.0759$

Time per mounting stud:

(1) $\frac{0.0603}{4} = 0.0150$

(2) $\frac{0.0553}{4} = 0.0135$

(3) $\frac{0.0759}{4} = 0.0189$

On Curve 1, these values are plotted against panel area. The resultant curve is a straight line. The data available do not justify stating that this is an ironclad fact, but since these are all the data available, it must be assumed that they are correct.

From Curve:

Eq. (1). Time for putting in one mounting stud complete = $0.0119 + 0.000028P$, where P = panel area in square inches.

Name Plates:

Data:

		Reference
Lay out 2 holes for name plate	0.0072	S-1
Drill 1 hole in cover	0.0035	S-5
Lay on name plate and rivets	0.0038	S-1
Lay on name plate and rivets	0.0040	S-3
Lay on name plate and rivets	0.0086	S-5
Lay on name plate and rivets	0.0074	S-6
Lay on name plate and rivets	0.0080	S-7
Lay on name plate and rivets	0.0113	S-12
Rivet 2 rivets	0.0056	S-1
Center punch 2 holes	0.0070	S-5
Lay out position of name plate	0.0113	S-2
Mark position 4 holes	0.0068	S-5
Center punch 4 holes	0.0092	S-5
Place on name plate and rivets and cut off 2 rivets	0.0075	S-2
Cut off 2 rivets	0.0029	S-6
Mark position 2 holes	0.0044	S-5
Get name plate and rivets	0.0041	S-7
Get name plate and rivets	0.0071	S-10
Measure for 2 name plates and mark holes	0.0334	S-10
Center punch 8 holes and chalk around	0.0231	S-10
Get 3 name plates and measure position	0.0043	S-11
Mark position 8 holes	0.0131	S-11
Get 3 name plates, measure position, and mark 8 holes	0.0130	S-12
Center punch 8 holes	0.0116	S-10

The procedure in putting on a name plate is as follows:

Lay out position of name plate
Scribe N holes
Center punch N holes
Drill N holes
Lay on name plate and rivets
Cut off 2 rivets $\times \frac{N}{2}$
Rivet 2 rivets $\times \frac{N}{2}$ where N = number of holes in name plate.

Lay out position of name plate.

From S-2 = 0.0113:

(1) Measure for 2 name plates and scribe 8 holes	0.0334	S-10
(2) Scribe 8 holes	0.0131	S-11

(1) − (2) = 0.0334 − 0.0131 = 0.0203 = measure for 2 name plates.

$$\frac{0.0203}{2} = 0.0102 = \text{measure for 1 name plate.}$$

(1) Time allowed for layout 0.0113

Scribe N holes
Mark position 4 holes—0.0068
Mark position 2 holes—0.0044
Mark position 8 holes—0.0131
Plotting this, the Y intercept = time to get ready to mark holes = 0.0013

From curve $\frac{\text{ordinate} - 0.0013}{\text{abscissa}} = 0.0015$

(2) Time to scribe N holes $= 0.0013 + 0.0015 \times N$
where N = number of holes.

Center punch N holes
Center punch 2 holes = 0.0070
Center punch 4 holes = 0.0092
Center punch 8 holes = 0.0116
Plotting this, the curve is drawn at a fair average value taking the data as a whole. Y intercept = 0.0060. From curve $\frac{\text{ordinate} - 0.0060}{\text{abscissa}} =$ 0.00075

(3) Time to eenter punch N holes $= 0.0060 + 0.0075 \times N$
where N = number of holes.

Drill N holes
Drill 1 hole in cover = 0.0031
(4) Drill N holes in cover $= 0.0031 \times N$
Lay on name plate and rivets:

From time-study data, Curve 4 is plotted. Neither the length of the operation nor the accuracy of the data warrants including such a curve in the final formula. Therefore, the approximate broken-line curves are used. The formula to be used up to panel area $= P = 375$ square inches.

(5) Time to lay on name plate and rivets

$$= 0.0032\frac{N}{2} + 0.000018 \times P \times \frac{N}{2}$$
$$= 0.0016N + 0.000009 \times P \times N$$

where N = number of rivets. By actual observation the time required to insert 2 rivets differed negligibly from the time required to lay on name plate and insert 2 rivets.

(5) Above panel area $= P = 375$ square inches. Time allowed $= 0.0100N$

Cut off rivets = cut off 2 rivets $\times \frac{N}{2}$

(6) $$= 0.0029 \times \frac{N}{2} = 0.00145N$$

Rivet rivets = rivet 2 rivets $\times \frac{N}{2}$

(7) $$= 0.0056 \times \frac{N}{2} = 0.0028N$$

Time allowed per name plate = (1) + (2) + (3) + (4) + (5) + (6) + (7).

(1) $= 0.0113$
(2) $= 0.0013 + 0.0015N$
(3) $= 0.0060 + 0.00075N$
(4) $= \quad 0.0031N$

$$(6) = \quad 0.00145N$$
$$(7) = \quad 0.0028N$$
$$(5) = \quad 0.0016N + 0.000009PN$$
$$\text{or} \quad 0.0100N$$

*Eq. (2) $= 0.0186N_1 + 0.0112N + 0.000009PN$ for panels up to 375 square inches.

*Eq. (3) $= 0.0186N_1 + 0.0196N$ for panels above 375 square inches.

Where N = Number of holes in name plates.
N_1 = Number of name plates.
P = Panel area in square inches.

Eq. (4). Time allowed for laying out holes per name plate = (1) + (2) + (3) $= 0.0186N_1 + 0.00225N$.

Then in operation 2, "assemble panel to box," where name-plate holes are already drilled, apply the following equations:

Time allowed to put on name plates after holes are drilled = (4) + (5) + (6) + (7).

Eq. (5) $= 0.00585N + 0.000009PN$ for panels up to 375 square inches.

Eq. (6) $= 0.01425N$ for panels above 375 square inches.

Prepare Electric Hand Drill:

0.0121 hour to be allowed per box whenever electric hand drill is used. This is allowed because with two men using the same drill there is some delay in getting electric drill and putting in the proper-sized drill.

Rubber Washers:

Place rubber washer on stud

(1) Place 3 rubber washers on studs	0.0120	*S*-1
(2) Place 4 rubber washers on studs	0.0103	*S*-3

(1) was selected from only one study while (2) was selected from several. Thus (2) may be considered the more accurate.

Using this value,

$$\text{Time allowed per rubber washer} = \frac{0.0103}{4} = 0.0026.$$

Place Panel in Box:

The data do not show any definite variation of time with panel size, as might be expected. Therefore, an average value is selected and the number of men required to lift the panel taken into account.

Eq. (7). Time allowed per panel $= 0.0095 \times M$ *S*-3

where M = number of men.

Bolt Panel to Mounting Stud:

Data:

Place 6 washers	0.0101	*S*-1
Put on 3 nuts with fingers	0.0104	*S*-1
Tighten 3 nuts with wrench	0.0125	*S*-1
Put on 8 washers	0.0138	*S*-3
Put on 1 nut with fingers	0.0025	*S*-5
Tighten 4 nuts	0.0112	*S*-3

* These equations apply only when name-plate holes have not been previously laid out and drilled. When operation 1 is "lay out box for drilling," apply Eq. (4).

(1) Place on 1 washer $= \frac{0.0101}{6} = 0.00169$ or $\frac{0.0138}{8} =$
0.00172, say 0.0017
(2) Put on 1 nut with fingers 0.0255
(3) Tighten 1 nut $\frac{0.0112}{4} = 0.0038$ 0.0038

Time allowed to bolt panel to mounting stud = 0.0017 + 0.0025 + 0.0038 = 0.0080 per bolt.

Cover Lock:

Data:

Lay out cover lock position	0.0107	*S*-1
Put in 2 rivets and prepare for riveting	0.0057	*S*-1
Place on cover lock	0.0113	*S*-1
Rivet 2 heavy rivets	0.0125	*S*-3
Adjust and remove box	0.0196	*S*-2
Time to remove box (from below)	0.0049	*S*-7
Time to adjust cover lock = 0.0196 − 0.0049 =	0.0147	

Time to put on cover lock complete =

0.0107 + 0.0057 + 0.0113 + 0.0126 + 0.0147 = 0.0550

Chalk Mark Holes:

Data:

Chalk mark 4 holes for filing	0.0120	*S*-2
Mark around 6 punch points	0.0065	*S*-8
Chalk 6 lugs	0.0099	*S*-9
Chalk 7 lugs	0.0204	*S*-10
Center punch 8 holes and chalk around	0.0181	*S*-11
Chalk around 8 holes = 0.0181 −* 0.0116 =	0.0065	
Chalk 4 mounting brackets	0.0116	*S*-11

There seems to be very little agreement here. In general it takes less time to circle a punch point than to chalk an area or mark a hole for filing. By selection:

Time allowed to mark around 1 punch point = 0.0008 per point.
Time allowed for all other chalking = 0.0116 overall.

Remove Panel from Box:

By selection from data.
Eq. (8). Time allowed to remove panel from box = $0.0035M$ *S*-2
where M = number of men required.

File Ream Holes in Panel:

By selection from data.
Time allowed to file ream hole in panel = 0.0144 per hole *S*-4

NOTE: This is to be allowed only when holes in box are not laid out using panel to be assembled as template.

Template:

Where template is used for laying out holes in cover, the time allowed will be no different from the time otherwise allowed.

* 0.0116 = time to center punch 8 holes.

Bolts (without Nuts) Screwing into Tapped Holes:

Data:

	(1) Put in 4 bolts by hand	0.0440	*S*-12
	(2) Tighten 4 bolts with wrench	0.0224	*S*-2
	(3) Put in 1 bolt with fingers	0.0052	*S*-6
	(4) Tighten 2 bolts with screwdriver	0.0045	*S*-4
	(5) Tighten 1 bolt with wrench	0.0056	*S*-4
	(6) Put in 1 bolt with fingers and tighten	0.0068	*S*-4
	(7) Tighten 1 side bolt with pliers	0.0056	*S*-4
*	(8) Tighten 1 bolt with screwdriver	0.0038	*S*-6

$$\left.\begin{array}{ll}(1)\ \dfrac{0.0440}{4} = 0.0110 \text{ per bolt} \\ (3)\ \qquad 0.0052 \text{ per bolt}\end{array}\right\}\text{fingers}$$

$$\left.\begin{array}{ll}(2)\ \dfrac{0.0224}{4} = 0.0056 \text{ per bolt} \\ (5)\ \qquad 0.0056 \text{ per bolt} \\ (7)\ \qquad 0.0056 \text{ per bolt}\end{array}\right\}\text{wrench}$$

$$\left.\begin{array}{ll}(4)\ \dfrac{0.0045}{2} = 0.0023 \text{ per bolt} \\ (8)\ \qquad 0.0038 \text{ per bolt}\end{array}\right\}\text{screwdriver}$$

Time allowed to put in 1 bolt with wrench = (3) + (2) = 0.0108 per bolt.

Time allowed to put in 1 bolt with screwdriver = (3) + (8) = 0.0090 per bolt.

Get Box:

Handling time should vary with size of box but as boxes are located in different parts of stock pile, it is impossible to do other than try to make a fair selection from data.

Time allowed to get box to bench = 0.0075 . . . . *S*-3

Get Panel:

These are more uniformly placed. Plotting handling time *versus* panel area gives Curve 5. The average curve at these points is a straight line.

Eq. (9). Time allowed to get panel to box $= 0.0053 + 0.000031P$

where P = panel area in square inches

Cut Off Brass Bolts:

By computation and selection the value 0.0101 per 7 bolts was obtained from *S*-3. Time per bolt $= \dfrac{0.0101}{7} = 0.0015$ per bolt. *S*-5 gives 0.0051 per 3 bolts, or $\dfrac{0.0051}{3} = 0.0017$ per bolt.

Time allowed to cut off brass bolts = 0.0015 per bolt.

Fit Panel into Position:

The smaller the panel, the easier it is to fit in place. For convenience, draw an average straight-line curve through the scattered data points.

* This value will also be used in case of the Cline Controller where it is necessary to tighten the screws holding on the side plates and screens with a screwdriver.

Eq. (10). Time allowed to fit 1 panel = $0.000035P - 0.0020$,
where P = panel area in square inches.

This term should be disregarded for panels below 58 square inches in area, as no fitting is necessary in the small sizes.

Tying on Tags:

Tie on instruction envelope	0.0073	*S*-5
Remove tag	0.0053	*S*-10
Replace tag	0.0204	*S*-10
Time allowed for all tying operations	0.0073*	

Remove Box:

Again there is no definite tendency for time to vary with size. Then selection gives:

Time allowed to remove box = 0.0049 per box *S*-7

Put in One Bolt Complete (Bolt with Nuts and Washers):

Put in 6 bolts and tighten 0.0791 *S*-7

$$\text{Time allowed to put in 1 bolt complete} = \frac{0.0791}{6} = 0.0132 \text{ per bolt.}$$

Scribe Mounting Bolt Hole for Drilling:

Data:

(1) Mark out 6 holes	0.0077	*S*-8
(2) Mark out 6 holes (2 men)	0.0089	*S*-9
(3) Mark out 7 holes (2 men)	0.0099	*S*-10
(4) Mark out 4 holes	0.0103	*S*-11
(5) Mark out 1 hole	0.0047	*S*-11

(1) $\frac{0.0077}{6} = 0.0013$

(2) $\frac{0.0089 \times 2}{6} = 0.0030$

(3) $\frac{0.0099 \times 2}{7} = 0.0028$

(4) $\frac{0.0103}{4} = 0.0026$

(5) $\frac{0.0047}{1} = 0.0047$

Time allowed to lay out hole = 0.0028 per hole *S*-10

Center Punch Mounting Bolt Holes for Drilling:

Data:

Center punch 6 holes (0.0015 per hole)	0.0090	*S*-8
Center punch 1 hole	0.0039	*S*-10
Center punch 1 hole	0.0061	*S*-11

These values vary widely. Use selection:

Time allowed to center punch 1 hole = 0.0039 per hole.

* Tags come only on Type *F* or the *AC* apparatus since this is tested before assembling to box. The type *C* being tested after assembling has no tag. Since boxes are used for both Type *F* and *C*, allow $\frac{0.0073}{2}$, or 0.0036 on every box for tying.

Remove Panel:

Remove panel to stock pile	0.0078	*S*-10
Remove panel to stock pile	0.0056	*S*-9
Remove panel to stock pile	0.0086	*S*-10
Time allowed to remove panel	0.0078	

Put in One Stud Complete:

Allow same as put in 1 bolt complete	0.0132 per stud	

As a result of the combinations made in the element analysis, it is possible to boil the values on two original sheets of master tables down into the few values contained on the condensed master table shown in Fig. 58. A good explanation of all constants and variables was given under Element Analysis, together with the reasoning followed in determining their magnitude so that it need not be dwelt on further here.

The next step is to derive the final formula expression and to write the formula report. As has been stated, the operations involved in mounting panels in enclosing cabinets divide naturally into three distinct classes. The formula expression for this work may be handled in several different ways, but for this particular case, it seemed best to make three subformulas and to refer to them in one master formula which explains all the general details of the work. Thus when establishing time values on one class of work, one will not be confused by values applying to the other classes.

The master formula report gives all of the general aspects of the work and the method of compiling the formula. The subformulas give in detail the formula expression, synthesis, and such details as pertain especially to the class of work which they cover. The formula report is self-explanatory and needs no elaboration. A study of the synthesis given under the subformulas will show just what values were combined to make the constants shown in the formula expression.

Formula F-13 No. 7.
May 1, 1926.

Part:

Panel enclosing cabinets or boxes.

Operation:

Lay out box for drilling and assemble panel to box.

Work Station:

Bench.

MASTER TABLE OF DETAIL TIME STUDIES

SHEET No. 1
OF 1 SHEETS

FORMULA F-13 #7
DATE May 1st 1926
PART Enclosing Cabinets
OPERATION Layout Panel for Drilling & Assemble Panel to Box
PERFORMED ON Bench
COMPILED BY J. A. Smith
TIME STUDY DEPARTMENT

					S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15	S-16	S-17	S-18	S-19	S-20
JOB CHARACTERISTICS	STUDY				#1 4-4-24	#2 4-4-24	#4 4-4-24	#1 4-5-24	#2 4-5-24	#3 4-5-24	#3 4-8-24	#2 4-7-24	#1 4-9-24	#1 4-8-24	#3 4-4-24	#1 4-11-24								
	OPERATOR				Hiler	Hiler	Hiler	Gottheret	Gottheret	Hiler	Hiler	Hiler	Hiler Gottheret	Hiler Gottheret	Hiler	Hiler Marian								
	Skill				Good	Good	Good	Good	Average	Good	Good	Good	Good	Good	Good	Good								
	Effort				Excellent	Excellent	Excellent	Average	Average	Good	Excellent	Good	Good	Good	Excellent	Good								
	Assemble				✓	✓	✓	✓	✓	✓	✓													
	Layout											✓	✓	✓	✓	✓								
	Panel Area				50	168	108	778	280	127.5	296	296	575	910	127.5	1030								
	Drawing No.				610449	315866	435819	423517	415412	371827	371902	371902	401342	602278	371827	617930								
	How Mounted				Mounting Stud	Mounting Brackets	Mounting Stud		Mounting Stud	Mounting Brackets	Mounting Brackets					Mounting Brackets								
								CLINE																
SYMBOL	OPERATION DESCRIPTION	TIME ALLOWED (HOURS)	REFERENCE																					
A	Put in One Mounting Stud Complete	Eq. #1		V	0150		0135		0198															
B	Put on One Name Plate Complete	Eq. #2 or #3		V	0316	0478	0351		0419							1048								
C	Prepare Electric Hand Drill	0121	S-1	C	0121	0127	0102		0166							0048								
D	Place One Rubber Washer on Stud	0026	S-3	M	0040		0026																	
E	Place Panel in Box	Eq. #7		V	0120	0121	0095	0086	0060	0061	0072		0014	0148	0095	0043								
F	Bolt Panel to Mounting Stud per Stud	0080	Comp. E.A.	C	0110		0065		0065															
G	Put on One Coverlock	0550	Comp. E.A.	C	0519		0534																	
H	Remove Box	0049	S-7	C			0044		0045	0061	0049	0084	0035	0105	0042									
I	Chalk Areas or Mark Holes for Filing	0116	S-11	C		0120						0065	0099	0204	0116									
J	Put in One Bolt with Wrench	0108	S2 & 4	C		0108		0108								0110								
K	Remove Panel from Box	Eq. #8		V		0035		0029			0044				0058									
L	Get Box	0075	S-3	C			0075	0062	0039	0091	0065	0121	0071	0222	0116									
M	Get Panel from or Remove Panel to Stack Pile	Eq. #9		V			0081		0123	0110	0173	0056	0078	0107		0122								
N	Cut Off One Brass Bolt on Back of Panel	0015	S-3	M			0015		0017															
O	Layout All Name Plate Holes for Drilling	Eq. #4		V											0355									
P	Fit Panel into Position	Eq. #10		V				0166	0070	0031	0084		0136			0158								
Q	Set Box on Floor	0100	S-6	C					0094	0100	0083			0084										
R	Tie or Untie Tags	0036	Comp. E.A.	C										0053										
S	Cut One Hole in Side of Box, Finish File & Fit Cover Plate Complete	2907	S-7	M							2907													
T	Layout and Saw One Mounting Support Complete	1249	S-7	M							1249													
U	Layout Side Hole, Center Punch Around (Layout & Place Template)	1360	S-8	M								1360												
V	Layout One Hole for Drilling	0028	S-10	C								0013	0030	0028	0026									
W	Center Punch One Hole	0039	S-10	C								0015		0039	0061									
X	Chalk Mark Around One Punch Point	0008	S-11	C								0010			0008									
Y	Layout and Mark One Hole in Side of Box	0298	S-11	M											0298									
Z	Put in Switch Handle Complete	0827	S-6	M						0827														
A1	Put on One Name Plate after Holes are Drilled	Eq. #5 or #6		V						0152	0232													
B1	File Ream One Hole in Panel	0144	S-4	M				0144																

(S-4:) THESE OPERATIONS WERE SELECTED FROM A STUDY ON MOUNTING A CLINE CONTROLLER TO EKE OUT AVAILABLE DATA

(S-7:) NO PANELS FITTED PROPERLY SO MOUNTING TIME IS DISREGARDED ON THIS STUDY

FIG. 58.—Master table compiled for panel mounting formula.

Allowed Time:

See Sub A, Sub B, and Sub C of this formula.

Application:

This formula applies to laying out brackets in enclosing cabinets for drilling and to assembling panels in enclosing cabinets as done in section *F*-13 under conditions and with equipment as of May 1, 1926, except Cline Controllers.

Analysis:

The tools and accessories needed are screwdriver, pliers, socket wrenches, hammer, center punch, scribe, stiff wire 12 inches long, taps and holder, electric hand drill, drills, wire cutters (large and small), heavy iron riveting block, small metal block for riveting, round file, flat file.

The materials needed are nuts, bolts, flat washers, lock washers, rubber washers, studs, plugs for resistance frames, light and heavy rivets, name plates, trade marks.

The group leader gets all materials to the men, 5 per cent being allowed to cover his time.

All boxes and panels are kept in a stock pile close to work bench.

Panels are mounted in two different ways, on mounting studs and on mounting brackets. For convenience, the following subdivisions of the work may be made:

A. Assemble panel to box (when mounting studs are used).
B. Lay out all holes for drilling (when mounting brackets are used).
C. Assemble panel to box (when mounting brackets are used).

A subformula will be derived for each case.

Boxes and panels are brought to the stock pile by the move men. Group leader handles information and gets name plates stamped. Men working on layout and assembly have no other duties outside the actual work performed on boxes. Finished boxes are removed by move men.

Whenever electric hand drill is used, 0.0121 hour is allowed per box. This is allowed because with two men using the same drill, there is necessarily some delay in getting electric drill and putting in the proper size of drill.

Where template is used for laying out holes in cover, the time allowed will be the same as though a template were not used.

Tags come only on Type *F* or the *AC* apparatus since this is tested before assembly to box. The Type *C* being tested after assembly has no tag. Since the same size of box is used for both Type *F* and *C*, $\frac{0.0073}{2}$ or 0.0036 or one-half the time per tag will be allowed on every box for tying on tag.

In the larger sizes of boxes taking mounting studs, it is easiest to put the mounting studs in with the box on the bench and to put the panel in with the box on the floor. 0.0100 hour is to be allowed for setting box on floor.

Time for file reaming holes is to be allowed only when holes in box are not laid out, using panel to be assembled as template.

Boxes with Screen Sides. Cline Controllers:

At present, only one style of box is built up in *F*-13, only two different styles of resistance frames are made, and only two differant styles of screen-sided boxes used. These are all used for the two types of Cline Controllers.

The time values for these jobs may be set by time study rather than by formula. Certain operations, occurring only in this work, would have to be represented by a number of symbols in the formula. This would give a long unwieldy looking expression, about half of which might never be used if no new work of this type were introduced into the shop.

Therefore, studies on this work will not be used in compiling the formulas but will be kept for reference in case sometime in the future other work of a similar nature comes along.

Special Side Hoels on Navy Jobs:

Navy jobs require that a hole be cut in either side of box for leads. These holes are covered with plates to protect the interior of the box from dust, etc. when hole is not used. The time required to lay out, finish, and fit up such a hole is covered by operations *S* and *U* in Table of Details.

The only standard box in which these holes are cut at the present time is the box covered by Drawing 371902. In this case the mounting brackets have to be sawed to fit. Operation *T* takes care of this.

It will not be necessary to carry these values in the formula, but they will be left in the Table of Details to be available for reference.

General Practice for Putting Name Plates on Boxes:

No hard and fast rules may be laid down for putting name plates on boxes, but the following is the general practice. In any doubtful case, the actual practice should be checked from the floor.

There are three types of name plates:

1. Circular trade mark (2 or 4 holes).
2. Instructions for ordering renewal parts (4 holes).
3. Name plate giving capacities, *S* No., *S. O.* No., Serial No., etc. (2 or 4 holes).

Cline Controllers take no name plate of any sort on box.

All other boxes with covers take the trade-marks. The size of trade marks used is proportional to the cover area. The group leader has a table of the proper size to use. The larger trade marks from 4 inches in diameter up have 4 holes.*

Small boxes containing single-unit panels take the trade mark only.

All boxes other than Cline and the above small boxes take the instruction plate.

Boxes without covers take the instruction plate only, mounted on one side of the box.

The general name plate (3) is mounted on the panel whenever possible. When there is no room on the panel, the name plate is mounted on the box.

These general rules apply to all standard boxes.

* These four-hole trade marks are used on covers larger than 600 square inches.

TIME STUDIES

Study Number	Date	Time Study Taken by
S-1 —1	4–4–24	H. B. M.
S-2 —2	4–4–24	"
S-3 —4	4–4–24	"
S-4 —1	4–5–24	"
S-5 —2	4–5–24	"
S-6 —3	4–5–24	"
S-7 —3	4–8–24	"
S-8 —2	4–7–24	"
S-9 —1	4–9–24	"
S-10—1	4–8–24	"
S-11—3	4–4–24	"
S-12—5	4–4–24	"
S-13—2	4–9–24	"
S-14—1	4–11–24	"

TABLE OF DETAIL OPERATIONS

Symbol	Operation Description	Decimal Hours	Reference
A	Put in one mounting stud complete	Eq. 1	
B	Put on one name plate complete	Eq. 2 or 3	
C	Prepare electric hand drill	0.0121	S-1
D	Place one rubber washer on stud	0.0026	S-3
E	Place panel in box	Eq. 7	
F	Bolt panel to mounting stud, time per stud	0.0080	Computed
G	Put on one cover lock	0.0550	Computed
H	Remove box	0.0049	S-7
I	Chalk areas or mark holes for filing	0.0116	S-11
J	Put in one bolt with wrench	0.0108	S-2-4
K	Remove panel from box	Eq. 8	
L	Get box	0.0075	S-3
M	Get panel from or remove panel to stock pile	Eq. 9	
N	Cut off brass bolt on back of panel	0.0015	S-3
O	Lay out all name plate holes for drilling	Eq. 4	
P	Fit panel into position	Eq. 10	
Q	Set box on floor	0.0100	S-6
R	Tie or untie tags, etc	0.0036	Computed
S	Cut one hole inside of box, finish file and fit cover plates complete	0.2907	S-7
T	Lay out and saw one mounting support complete	0.1249	S-7
U	Lay out side hole, center punch around, lay out and place template	0.1360	S-8
V	Lay out one hole for drilling	0.0028	S-10
W	Center punch one hole	0.0039	S-10
X	Chalk mark around one punch point	0.0008	S-11
Y	Lay out and mark one hole in side of box	0.0298	S-11
Z	Put in switch handle complete	0.0827	S-6
A_1	Put on one name plate after holes are drilled	Eq. 5 and 6	
B_1	File ream one hole in panel	0.0144	S-4

Synthesis:

Equations to be Used in Connection with Formula.

Time for putting in one mounting stud complete in hours =

$$0.0119 + 0.000028P \qquad \text{Eq. 1}$$

Time for putting on name plates complete on panels up to 375 square inches in area =

$$0.0186N_1 + 0.0112N + 0.000009 \times P \times N \qquad \text{Eq. 2}$$

Time for putting on name plates complete on panels above 375 square inches in area =

$$0.0186N_1 + 0.0196N \qquad \text{Eq. 3}$$

Time for laying out holes for name plates only, in hours =

$$0.0186N_1 + 0.00225N \qquad \text{Eq. 4}$$

Time to put on name plates after holes are drilled, panels up to 375 square inches in area =

$$0.00585N + 0.000009\ P \times N. \qquad \text{Eq. 5}$$

Time to put on name plates after holes are drilled, panels above 375 square inches in area =

$$0.01425N \qquad \text{Eq. 6}$$

Time to place panel in box, in hours =

$$0.0095 \times M \qquad \text{Eq. 7}$$

Time to remove panel from box, in hours =

$$0.0035 \times M \qquad \text{Eq. 8}$$

Time to get panel, in hours =

$$0.0053 + 0.000031P \qquad \text{Eq. 9}$$

Time to fit panel into position, in hours

$$0.00035P - 0.0020 \qquad \text{Eq. 10}$$

where M = number of men performing the operation.
N = number of holes in name plate.
N_1 = number of name plates.
P = panel area in square inches.

Also see subformulas.

Inspection:

After assembly cabinets are inspected to see that panels are firmly and properly placed, that box is complete in all its parts, that cover fits, and that proper name plates are in place.

Payment:

Standard-time group plan.

Approved:

Time-study Supervisor	Time-study Department

Formula F-13 No. 7-A.
May 1, 1926.

Part:

Enclosing cabinets or boxes in which mounting studs are used.

Operation:

Assemble panel to cabinet, put on all name plates complete.

Work Station:

Bench.

Allowed Time:

$0.0314 + 0.0550C + 0.0095M + 0.0112N + 0.0186N_1 + 0.000066P + 0.000009PN + 0.000028PY + 0.0015R + 0.0225Y$ for panels up to 375 square inches.

$0.0414 + 0.0550C + 0.0095M + 0.0196N + 0.0186N_1 + 0.000066P + 0.000028PY + 0.0015R + 0.0225Y$ for panels above 375 square inches in area,

where C = number of cover locks put on.
M = number of men required to handle panel.
N = number of holes in all name plates put on.
N_1 = number of name plates.
P = Area of panel in square inches.
R = number of brass connection bolts on back of panel which must be cut off.
Y = number of mounting studs.

Application:

This subformula applies to all work of assembling panel to cabinet, done in F-13 at the present time, where panel is mounted on mounting studs.

Procedure:

Get box, place mounting studs in box, put rubber washers on studs (if large box, set on floor), get panel, place panel in box, fit in place, bolt panel to mounting studs, prepare electric hand drill, put on name plates as specified, put on cover lock if specified, and if necessary, cut off brass connection bolts on back of panel before assembling.

Synthesis:

$C + H + L + R$ + [constant from Eq. (9)] − [constant from Eq.(10)] = $0.0121 + 0.0049 + 0.0075 + 0.0036 + 0.0053 - 0.0020 = 0.0314$ = constant for panels up to 375 square inches in area.

Above constant $+ Q = 0.0314 + 0.0100 = 0.0414$ = constant for panels above 375 square inches in area.

Above constants + Eq. (1) + Eq. (2) or (3) + Eq. (7) + Eq. (9) + Eq. (10) $+ G + N$ = formula expressions given under Allowed Time.

A = Eq. (1) − put in one mounting stud complete $= 0.0119 + 0.000028P$. Time-study values of time to put in one mounting stud, plotted against panel area, gives a straight line. The above equation is the algebraic expression for this line.

B = Eq. (2) or (3) − place on name plates complete $= 0.0186N_1 + 0.0112N + 0.000009PN$ for panels up to 375 square inches in area and

$0.0186N_1 + 0.0196N$ for panels above 375 square inches in area. Curves were plotted from time-study data of time to scribe holes *versus* number of holes, time to center punch holes *versus* number of holes, time to lay on name plate and two rivets *versus* panel area. The algebraic expression for each curve was found. The time to drill holes, cut off rivets, and rivet rivets was derived from the data expressed in terms of N. The summation of those algebraic quantities plus a constant for layout position of name plate (per name plate) gives the above equations.

E = Eq. (7) – place panel in box = $0.0095M$. The time to place panel in box was found to be fairly constant. Twice this constant time is allowed when it requires two men to handle the panel.

M = Eq. (9) – get panel = $0.0053 + 0.000031P$. This expression was found by plotting time to get panel *versus* panel area. The larger panels are heavier and hence harder to carry to the bench than the smaller.

P = Eq. (10) – fit panel in place $\doteq 0.000035P - 0.0020$. This expression was found by plotting time to fit panel in place *versus* panel area. When the panel area falls under 58 square inches, the panel is considered to be so light that fitting time is negligible and henee below $P = 58$, Eq. (10) is omitted from the formula.

Inspection:

After assembly cabinets are inspeeted to see that panels are firmly and properly placed, that box is complete in all its parts, that cover fits, and that proper name plates are in place.

Payment:

Standard-time group plan.

Approved:

________________________	________________________
Time-study Supervisor	Time-study Department

Formula F-13 No. 7-B.
May 1, 1926

Part:

Enclosing cabinets or boxes in which mounting brackets or mounting lugs are used.

Operation:

Lay out all holes for drilling.

Work Station:

Bench.

Allowed Time:

$0.0346 + 0.0130M + 0.00233N + 0.0186N_1 + 0.000062P + 0.0298S + 0.0067X$,

where M = number of men required to handle panel.
N = number of holes in all name plates.
N_1 = number of name plates.
P = panel area in square inches.
S = number of holes laid out for switch handles.
X = number of mounting brackets or lugs.

Application:

This formula applies to all layout work on boxes using mounting supports or lugs as done in F-13 at this time.

Procedure:

Get box, chalk brackets or lugs, get panel, place panel in box, scribe holes, remove panel from box, center punch holes, lay out all name-plate holes, chalk circle around each name-plate hole, punch mark, remove panel, remove box, and lay out and mark one hole for switch handle in side of box.

Synthesis:

$H + I + L + 2 \times$ constant from Eq. (9) $= 0.0049 + 0.0116 + 0.0075 + 0.0106 = 0.0346 =$ constant per box.

$0.0346 +$ Eq. (4) $+$ Eq. (7) $+$ Eq. (8) $+$ Eq. (9) $+ Y + X$ (number of name-plate holes) $=$ formula expression given under Allowed Time.

$O =$ Eq. (4) $-$ lay out all name-plate holes for drilling $= 0.0186N_1 + 0.00225N$. This equation is simply that part of Eq. (2) or (3) which takes care of layout position of name plate, seribe holes and center punch holes. See Synthesis Formula F-13 No. 7-A.

$K =$ Eq. (8) $-$ remove panel from box $= 0.0035M$. The time to remove a panel from a cabinet was found to be fairly constant. When two men are required to handle the panel, twice as much time is allowed.

For explanation of E and M, or Eqs. (7) and (9), see Synthesis Formula F-13 No. 7-A.

Inspection:

No inspection after this operation.

Payment:

Standard-time group plan.

Approved:

Time-study Supervisor	Time-study Department

Formula F-13 No. 7-C.
May 1, 1926.

Part:

Enclosing cabinets or boxes in which mounting brackets or mounting lugs are used.

Operation:

Assemble panel to cabinet, rivet on name plate.

Work Station:

Bench.

Allowed Time:

$0.0193 + 0.0550C + 0.0827H + 0.0095M + 0.00585N + 0.000066P + 0.000009PN + 0.0015R + 0.0229X + K \quad (0.0116 + 0.0144F + 0.0130M)$ for panels up to 375 square inches in area.

$0.0193 + 0.0550C + 0.0827H + 0.0095M + 0.01425N + 0.000066P + 0.0015R + 0.0229X + K(0.0116 + 0.0144F + 0.0130M)$ for panels above 375 square inches in area,

where C = number of cover locks put on.
F = number of holes file reamed.
H = number of switch handles mounted complete.
K = use as special value when conditions make it necessary to lay out holes other than from the panel to be mounted.
M = number of men required to handle panel.
N = number of holes in all name plates.
P = area of panel in square inches.
R = number of brass connection bolts on back of panel which must be cut off.
X = number of mounting brackets or lugs.

Application:

This formula applies to all work of assembling panel to cabinet as done in F-13 at this time, where the panel is mounted on mounting brackets or lugs, except Cline Controllers.

Procedure:

Get box, get panel, place panel in box, fit in place (chalk holes for filing, remove panel, file ream holes, and replace panel if necessary), place rubber washers under holes, put in holding-down bolts, put on name plates (put on cover lock, put on switch lever, if necessary), tie on tag, and remove box.

Synthesis:

$H + L + R$ + (constant from Eq. (9)) − (constant from Eq. (10)) = $0.0049 + 0.0075 + 0.0036 + 0.0053 - 0.0020 = 0.0193$ = constant for each panel mounted on mounting brackets.

Above constant $+ G + I + B_1$ + Eq. (5), or Eq. (6) + 2 Eq. (7) + Eq. (8) + Eq. (9) + Eq. (10) = formula expression given under Allowed Time.

For E, K, M, and P or Eqs. (7), (8), (9), and (10), see Synthesis, Formula F-13 No. 7-A.

A_1 = put in name plate after holes are drilled = Eqs. (5) or (6) = $0.00585N + 0.000009PN$ or $0.01425N$ for panels up to or above 375 square inches in area, respectively. These equations are simply those parts of Eqs. (2) and (3) which take care of lay on name plate and rivets, cut off two rivets, and rivet two rivets. See Synthesis, Formula F-13 No. 7-A.

Inspection:

After assembly, cabinets are inspected to see that panels are firmly and properly placed, that the box is complete in all its parts, that cover fits, and that proper name plates are in place.

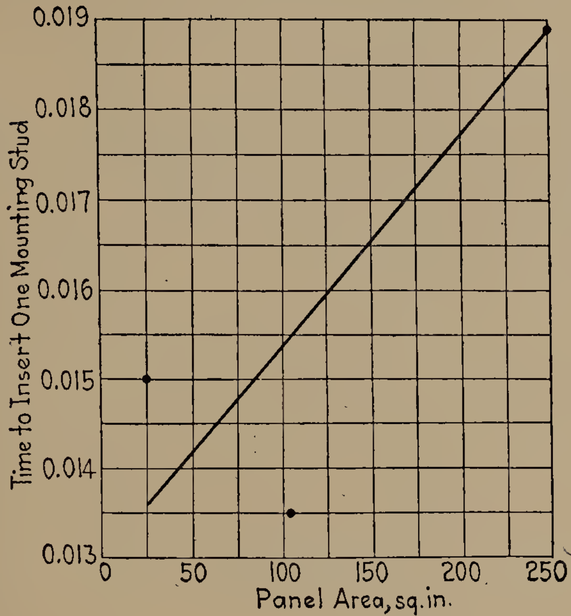
Payment:

Standard-time group plan.

Approved:

Time-study Supervisor

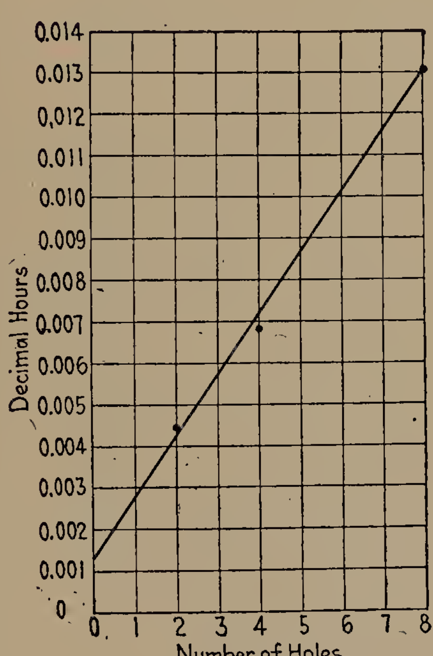
Time-study Department



Panel Area vs. Time to Insert Mounting Studs.

Reference:
S-1, S-2, S-5 and Element Analysis.

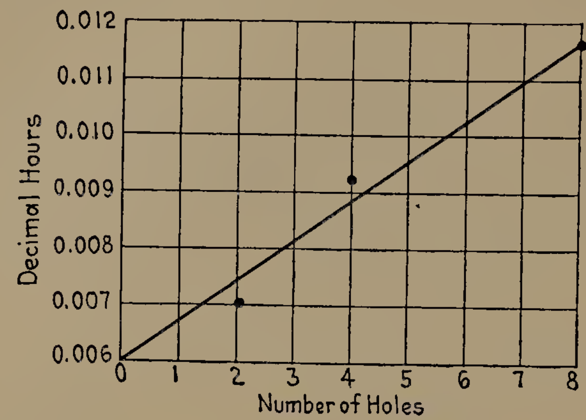
CURVE 1.



Number of Holes vs. Scribing Time.

Reference:
S-5 and S-11.

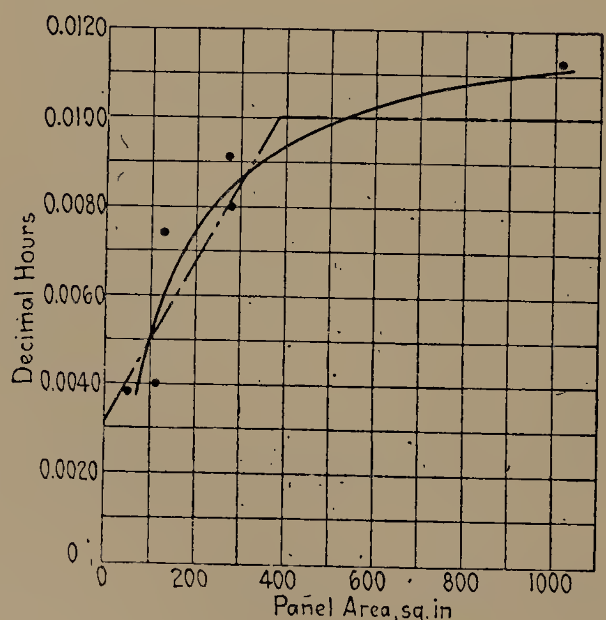
CURVE 2.



Number of Holes vs. Time to Center Punch.

Reference:
S-5 and S-12.

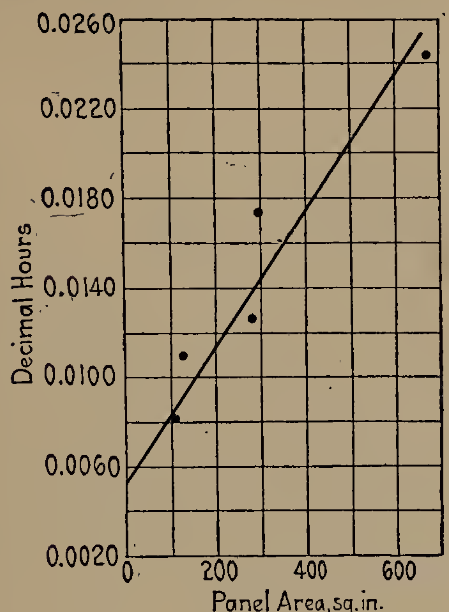
CURVE 3.



Panel Area vs. Time to Place Name Plate and Rivets.

References:
S-1, S-3, S-5, S-6, S-7 and S-12.

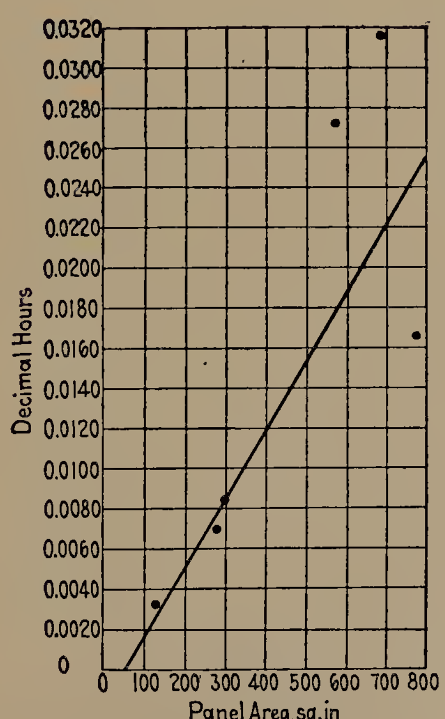
CURVE 4.



Panel Area vs. Time to Get Panel.

References:
S-3, S-5, S-6, S-7 and S-12.

CURVE 5.



Panel Area vs. Fitting Time.

References:
S-4, S-5, S-6, S-7, S-9 and S-12.

CURVE 6.

CHAPTER XXVIII

FORMULA FOR MILLING MACHINE

Almost everyone who has had any experience with incentive plans has recognized the fact that it is easier to set time allowances for machine work than it is for the so-called hand work. The reason for this is that the machine is much more definite and constant than man. Machine-tool builders and cutting-tool manufacturers conduct tests to determine the possibilities of their product and supply this information to their customers. There are any number of mechanical handbooks that contain data about the performance of machine and cutting tools. This information and the experience gained on a particular application makes possible the establishing of fairly accurate machining time. However, while much of the judgment has been eliminated in machine practice, there are still possibilities for considerable errors. Nearly all of the machining data given in handbooks and supplied by tool builders have been obtained under test conditions and cannot be used in a general way, but it does serve as an excellent guide. Obviously parts that are frail and that extend out relatively far from the point of support cannot stand the speed and feed that a solid block can. It is necessary, therefore, to determine good practice for particular conditions.

The formula example given in this chapter is for milling machine work, and it has been compiled for a particular department. There are thousands of different jobs varying in characteristics machined in this department, but as the formula shows, the performing of each job consists of a combination of details which are largely common to all jobs varying only in number of occurrences. The value of a formula such as this can be appreciated when it is considered that the group of machines to which it applies works on an average of 50 jobs daily.

This formula was originally compiled in standard data form. A separate formula number was assigned to the set-up data, the additional piece data, and the feed chart. Later a revision was made, and the data were put into approved formula form. The

manner of expressing the nature of a revision is thus illustrated by this example.

Formula F-1 No. 10.
Revision 1.
March 1, 1926.

Part:

Brass, cast iron, steel, copper, micarta, and fiber parts.

Operation:

Mill.

Work Station:

All milling machines in F-1 except 9966, 2038, and 924.

Allowed Time:

Set-up Time.—$0.2415 + 0.0260A_1 + 0.0173A_2 + 0.0670E + 0.0985F + 0.1160G + 0.0125O + 0.1150S + 0.0050S' + 0.0234U + 0.0719V + 0.2665X$.

Additional-piece Time: Fixture.—$(0.0053 + 0.0056A + 0.0048H + 0.0046J + 0.0037L + 0.0042L' + 0.0028P + 0.0007I + 0.0005I' + XT) \div P$ for small parts.

$0.0056A + 0.0048H + 0.0046J + 0.0037L + 0.0042L' + 0.0007I + 0.0005I' + XT +$ (0.0087 for medium parts or 0.0098 for large parts).

Vise.—$(0.0076 + 0.0032P + 0.0007I + 0.0005I' + XT) \div P$ for small parts.

$(0.0076 + 0.0036P + 0.0007I + 0.0005I' + XT) \div P$ for medium parts.

Clamp.—$0.0056A + 0.0048H + 0.0007I + 0.0005I' + XT +$ (0.0071 small or 0.0077 medium or 0.0088 large),

where A = number of clamps put on and taken off complete.
A_1 = use for first clamp put on and taken off complete.
A_2 = number of clamps put on and taken off complete minus (1).
E = number of end mills used.
F = number of fixtures used.
G = number of arbors used.
H = number of nuts put on and taken off clamps already in place.
I = number of inches table is moved forward.
I' = number of inches table is returned.
J = number of locating pins.
L = number of screws tightened by hand.
L' = number of screws tightened with wrench.
O = number of operations performed.
P = number of parts milled at one time.
S = number of cutters with collars minus one.
S' = number of cutters without collars minus one.
U = number of support heads used.
V = number of vises used.
X = index heads used.
XT = milling time: for simple surfaces, see chart, Fig. 21; for complex, take actual time on floor.

Small part, outside volume up to 30 cubic inches—weight up to 3 pounds.

Medium part, outside volume up to 250 cubic inches—weight up to 20 pounds.

Large part, outside volume above 250 cubic inches—weight above 20 pounds.

To compute first-piece time, when additional-piece time is less than 20 minutes, add twice additional-piece time to set-up time. When additional-piece time is more than 20 minutes, add 20 minutes plus time for one additional piece to set-up time.

Application:

This formula applies to all milling done on machines specified in *F*-1 on brass, cast iron, steel, copper, micarta, and fiber parts as done at this time with present equipment.

Reason for Revision:

This formula combines old *F*-1 Formulas 10, 11, and 15. Standard data are put into algebraic form, and an effort has been made to make the formula clearer and easier to apply. Actual time values are unaffected.

Analysis:

The tools and accessories needed are 6- and 12-inch scale, square, protractor, micrometer, surface gage, hermaphrodite calipers, screwdriver, hammer, wrenches, file, clamps, vise, fixtures, cutters, arbors, brush, liners, oil can, parallels.

Material is delivered to machines by storeroom attendant. Group leader sees that work is given out to men on machines. Finished material is checked for quantity by man under the control of the accounting department and is then removed by moveman.

Work is held on the milling table by clamps, vise, or fixtures. When a job is sufficiently active and when a fixture would appreciably cut down machining time, a fixture is made. Fixtures are also used on less active jobs, where great accuracy is required. All other jobs are held in a vise or are clamped to the milling table, depending on the nature of the job.

Milling time on all jobs which may be held firmly and which are free from vibration during cutting is taken care of by chart of cutting time. On all other jobs, actual time is found by observation and an allowance of 10 per cent added.

The group leader plans the work so that on the completion of one job, the operator has all the tools needed for the next job. The group leader also assists the operator to make the set-up and has the first piece inspected and passed before the remainder of the job is done.

To care for time spent in oiling and cleaning machines, 4 per cent must be added to first-piece and additional-piece values when work is done under the group plan. When work is done by an individual, oiling and cleaning time is taken care of by a separate time slip.

Jobs on which it is necessary to use an index head occur only once or twice a year. Therefore to avoid complication, the element allowed times for this class of work are given only in the Table of Detail Operations and must be applied from there directly.

Procedure:

Get part, place in vise, tighten vise and hammer part, run up table, start machine, engage feed, release feed, back off table, stop machine, release vise, and remove or lay aside part. The procedure for parts held in clamps or fixtures is similar to the above.

TIME STUDIES

Number	Date	Taken by
S-1	3-12-23	F. I. H.
S-2	3-13-23	"
S-3	3-16-23	"
S-4	3-16-24	"
S-5	3-23-23	"
S-6	3-23-23	"
S-7	3-26-24	"
S-8	3-26-23	"
S-9	Refer to data taken from Sec. *I*.	

TABLE OF DETAIL OPERATIONS

Symbol	Description of Operation	Time Allowed	Reference
A	Get job and drawing	0.0500	*S*-9
B	Get time slip	0.0400	"
C	Mark time on slip	0.0178	"
D	Go to tool room and get tools	0.1250	"
E	Check operation with drawing (per operation)	0.0125	"
F	Clean vise, fixture, index head, tail stock	0.0103	"
G	Put vise, fixture or tail stock on table	0.0084	"
H	Bolt vise, fixture or index head (2 bolts)	0.0156	"
I	Loosen vise, fixture, index head or tail stock (2 bolts)	0.0078	"
J	Remove vise from table	0.0118	"
K	Get 2 bolts and set in place in table slot	0.0180	"
L	Line up fixture	0.0348	"
M	Remove fixture from table	0.0036	"
N	Put index head on table	0.0263	"
O	Remove index head from table	0.0072	"
P	Clean tail stock	0.0103	"
Q	Tighten tail stock and adjust complete (2 bolts)	0.1330	"
R	Remove tail stock from table	0.0034	"
S	Put on support head	0.0060	"
T	Tighten support head	0.0086	"
U	Loosen support head	0.0024	"
V	Swing support head into position	0.0042	"
W	Tighten support head shaft	0.0084	"
X	Loosen support head shaft	0.0024	"
Y	Swing support head back	0.0060	"
Z	Remove support head	0.0037	"

TABLE OF DETAIL OPERATIONS.—(*Continued*)

Symbol	Description of Operation	Time Allowed	Reference
A-1	Put arbor in machine and tighten	0.0300	"
B-1	Remove arbor nut and collars	0.0030	"
C-1	Put collars and nut back on arbor	0.0147	"
D-1	Remove arbor	0.0268	"
E-1	Put on and tighten arbor nut	0.0178	"
F-1	Loosen arbor nut	0.0144	"
G-1	Remove arbor nut	0.0030	"
H-1	Lock spindle	0.0031	"
I-1	Unlock spindle	0.0032	"
J-1	Put end mill arbor in machine and tighten	0.0300	"
K-1	Put end mill on arbor	0.0020	"
L-1	Remove end mill from arbor	0.0300	"
M-1	Remove end mill arbor	0.0050	"
N-1	Put on first or single cutter and collars	0.0087	"
O-1	Put on each additional cutter (per cutter)	0.1150	"
P-1	For cutters having no collars between them	0.0050	"
	Part-handling Values		
Q-1	Get small part	0.0006	*S*-3
R-1	Get medium part	0.0007	*S*-1-2
S-1	Get large part	0.0010	*S*-9
T-1	Put small part in vise	0.0009	*S*-2
U-1	Put medium part in vise	0.0009	*S*-2
V-1	Tighten and hammer part	0.0024	*S*-5
W-1	Release vise	0.0009	*S*-6
X-1	Remove and lay aside small part	0.0017	*S*-7
Y-1	Remove and lay aside medium part	0.0020	*S*-1
Z-1	Remove cuttings from vise	0.0020	*S*-1
A-2	Put small part in fixture	0.0013	*S*-1
B-2	Put medium part in fixture	0.0018	*S*-1
C-2	Put large part in fixture	0.0021	*S*-1
D-2	Put locating pin in fixture (per pin)	0.0018	*S*-2
E-2	Remove locating pin (per pin)	0.0028	*S*-2
F-2	Tighten locating screw (per screw) by hand	0.0028	*S*-2
G-2	Release locating screw (per screw) by hand	0.0009	*S*-1
H-2	Tighten locating screw (per screw) with wrench	0.0024	*S*-9
I-2	Release locating screw (per screw) with wrench	0.0018	*S*-9
J-2	Remove small part and lay aside	0.0009	*S*-1-5
K-2	Remove medium part and lay aside	0.0009	*S*-1
L-2	Remove large part and lay aside	0.0014	*S*-1
M-2	Remove cuttings from fixture	0.0030	*S*-1
N-2	Put on clamp (per clamp)	0.0011	*S*-7
O-2	Tighten clamp (per clamp)	0.0024	*S*-7
P-2	Remove clamp (per clamp)	0.0021	*S*-7
Q-2	Put on nut (per nut)	0.0014	*S*-1

TABLE OF DETAIL OPERATIONS.—(*Continued*)

Symbol	Description of Operation	Time Allowed	Reference
R-2	Tighten nut (per nut)	0.0005	*S*-8
S-2	Release nut (per nut)	0.0005	*S*-1
T-2	Remove nut (per nut)	0.0014	*S*-4
U-2	Get wrench	0.0006	*S*-1
V-2	Lay aside wrench	0.0004	*S*-1
W-2	Put small part in fixture (hammer)	0.0031	*S*-7
X-2	Put dog on small, medium or large piece	0.0014	*F*-1 No. 8
Y-2	Place part between centers and adjust	0.0042	*F*-1 No. 8
Z-2	Remove part from between centers	0.0022	*F*-1 No. 8
A-3	Remove dog	0.0014	*F*-1 No. 8
B-3	Lay aside part	0.0008	*F*-1 No. 8
C-3	Place part in chuck on tail stock	0.0014	*F*-1 No. 8
D-3	Center (tighten chuck and adjust center)	0.0030	*F*-1 No. 8
E-3	Remove part from chuck and center and lay aside	0.0022	*F*-1 No. 8
F-3	Place part in chuck	0.0007	*F*-1 No. 1 Revision 1
G-3	Tighten chuck	0.0019	
H-3	Release chuck	0.0019	
I-3	Remove and lay aside	0.0007	
J-3	Put part in vise and line with scale	0.0015	*S*-3
K-3	Put copper clip on end of casting	0.0014	*S*-6
L-3	Micrometer	0.0026	*S*-9
M-3	Snap gage	0.0013	*S*-9
N-3	Calipers	0.0013	*S*-9
O-3	Scale	0.0016	*S*-9
P-3	Start machine	0.0003	*S*-7-8
Q-3	Stop machine	0.0014	*S*-2
R-3	Move table forward per inch or fraction thereof	0.0007	*S*-6-7-8
S-3	Return table per inch or fraction thereof	0.0005	*S*-3-7-8
T-3	Engage feed	0.0003	*S*-5-6-7-8

Synthesis:

Set-up Time.—$A + B + C + D + N\text{-}1 = 0.0500 + 0.0400 + 0.0178 + 0.1250 + 0.0087 = 0.2415$ = constant per set-up.

0.0260 = constant per first clamp. See Profile Data, Formula *F*-1 No. 17.

$J\text{-}1 + K\text{-}1 + L\text{-}1 + M\text{-}1 = 0.0300 + 0.0020 + 0.0300 + 0.0050 = 0.0670$ = constant per end mill.

$F + G + L + H + I + M + K = 0.0103 + 0.0084 + 0.0348 + 0.0156 + 0.0078 + 0.0036 + 0.0180 = 0.0985$ = constant per fixture.

$A\text{-}1 + B\text{-}1 + C\text{-}1 + D\text{-}1 + E\text{-}1 + F\text{-}1 + G\text{-}1 + H\text{-}1 + I\text{-}1 = 0.0300 + 0.0030 + 0.0147 + 0.0268 + 0.0178 + 0.0144 + 0.0030 + 0.0031 + 0.0032 = 0.1160$ = constant per arbor.

$U + V + W + X + Y = 0.0024 + 0.0042 + 0.0084 + 0.0024 + 0.0060 = 0.0234$ = constant per support head.

$F + G + H + I + J + K = 0.0103 + 0.0084 + 0.0156 + 0.0078 + 0.0118 + 0.0180 = 0.0719$ = constant per vise.

$F + N + H + I + O + K + P + G + Q + I + R + K = 0.0103 + 0.0263 + 0.0156 + 0.0078 + 0.0072 + 0.0180 + 0.0103 + 0.0084 + 0.1330 + 0.0078 + 0.0034 + 0.0180 = 0.2661$ = constant per index head.

Additional-piece Time.—$V\text{-}1 + W\text{-}1 + Z\text{-}1 + P\text{-}3 + Q\text{-}3 + 2T\text{-}3 = 0.0024 + 0.0009 + 0.0020 + 0.0003 + 0.0014 + 0.0006 = 0.0076$ = constant for vise work.

Q-1 or R-1 + T-1 or U-1 + X-1 or Y-1 = 0.0032 or 0.0036 = constant per small or medium piece in vise.

$M\text{-}2 + P\text{-}3 + Q\text{-}3 + 2T\text{-}3 = 0.0030 + 0.0003 + 0.0014 + 0.0006 = 0.0053$ = constant for small fixture work.

$Q\text{-}1 + A\text{-}2 + J\text{-}2 = 0.0006 + 0.0013 + 0.0009 = 0.0028$ = constant per small piece in fixture.

$R\text{-}1 + B\text{-}2 + K\text{-}2 + M\text{-}2 + P\text{-}3 + Q\text{-}3 + 2T\text{-}3 = 0.0007 + 0.0018 + 0.0009 + 0.0030 + 0.0003 + 0.0014 + 0.0006 = 0.0087$ = constant for medium work in fixture.

$S\text{-}1 + C\text{-}2 + L\text{-}2 + M\text{-}2 + P\text{-}3 + Q\text{-}3 + 2T\text{-}3 = 0.0010 + 0.0021 + 0.0014 + 0.0030 + 0.0003 + 0.0014 + 0.0006 = 0.0098$ = constant for large work in fixture.

$N\text{-}2 + O\text{-}2 + P\text{-}2 = 0.0011 + 0.0024 + 0.0021 = 0.0056$ = constant per clamp.

$Q\text{-}2 + R\text{-}2 + S\text{-}2 + T\text{-}2 + U\text{-}2 + V\text{-}2 = 0.0014 + 0.0005 + 0.0005 + 0.0014 + 0.0006 + 0.0004 = 0.0048$ = constant per nut on clamp already on.

$D\text{-}2 + E\text{-}2 = 0.0018 + 0.0028 = 0.0046$ = constant per locating pin.

$F\text{-}2 + G\text{-}2 = 0.0028 + 0.0009 = 0.0037$ = constant per locating screw tightened by hand.

$Q\text{-}1 + A\text{-}2 + Z\text{-}1 + J\text{-}2 + P\text{-}3 + Q\text{-}3 + 2T\text{-}3 = 0.0006 + 0.0013 + 0.0020 + 0.0009 + 0.0003 + 0.0014 + 0.0006 = 0.0071$ = constant for small part clamped to table.

$R\text{-}1 + B\text{-}2 + Z\text{-}1 + K\text{-}2 + P\text{-}3 + Q\text{-}3 + 2T\text{-}3 = 0.0007 + 0.0018 + 0.0020 + 0.0009 + 0.0003 + 0.0014 + 0.0006 = 0.0077$ = constant for medium part clamped to table.

$S\text{-}1 + C\text{-}2 + Z\text{-}1 + L\text{-}2 + P\text{-}3 + Q\text{-}3 + 2T\text{-}3 = 0.0010 + 0.0021 + 0.0020 + 0.0014 + 0.0003 + 0.0014 + 0.0006 = 0.0088$ = constant for large part clamped to table.

Inspection:

Inspected for size and finish.

Payment:

Standard-time group.

Approved:

Time-study Supervisor   Time-study Department

CHAPTER XXIX

FORMULA FOR ALLOY CASTINGS MOLDED ON BENCH

The formula example given in this chapter is for the brass foundry operation of bench molding. In this particular case, the work is of an extremely varied nature. The number of patterns molded in a flask varies from one to seven. Because of this great variation, it was believed, for a long time, to be out of the realm of incentive systems. At length, however, the idea was conceived of allowing a certain amount of time for each flask, regardless of the number of patterns contained therein. The foreman in charge was to see that each molder utilized the flask space to the best advantage, and the moveman or checker was to approve the number of molds made. The thought was that while there would be many inconsistencies over a pay period of 2 weeks, the average would be about right. As a matter of fact, the bonus earned was fairly consistent if the nature of the work remained the same from pay to pay, but the men were not satisfied, and it was difficult to make an equitable distribution of the costs. In slack times, there was a tendency not to crowd as many patterns into a flask as in good times, thus making the work on hand last longer. In general, the plan was found to be unsatisfactory; so the work was time studied with a view to making a formula. The time spent has been more than justified by increased production with consequent reduced costs to the company and by the satisfaction of the workers in having earnings directly proportional to effort. The operators now know the amount of time they are allowed for each casting, and the foreman is relieved from checking to see that the flask space is being used to the best advantage. The costing of the operation is definite and accurate. This example should clearly demonstrate the possibilities of formula application to foundry work.

Formula O-4 No. 7.
Nov. 1, 1924.

Part:
Alloy castings molded on bench.
Operation:
Mold.
Work Station:
Bench.
Allowed Time:
First-piece Time.
Simple: $0.0500 + 0.075D + 1.10$ (additional-piece time).
Medium: $0.1000 + 0.00188C' + 0.075D + 1.10$ (additional-piece time).
Complex: $0.1750 + 0.0077C' + 1.10$ (additional-piece time).
Additional-piece Time.

Simple: $\frac{0.2959}{A} + 0.00234C + 0.0207P + NB + R.$

Medium: $\frac{0.3013}{A} + 0.00384C + 0.0434P + NB + R.$

Complex: $\left(\frac{0.3936}{A} + 0.0129C + NB + R'\right) 1.10.$

Add 0.019 to above formulas for each frame necessary,
where A = see Table 1 or 1A.
B = see Table 2.
C = total length of parting line in inches.
C' = total length of parting line in match in inches.
D = use when cores are required.
N = number of eores.
P = number of parts per pattern.
R = 0.0150 when reinforcing is necessary.
R' = 0.0500 when reinforcing is neeessary.

Table 1.—Values of A for All Castings but Copper Blocks

A = 1 when greatest pattern area falls between 50 square inches and up.
A = 2 when greatest pattern area falls between 25 to 50 square inches.
A = 3 when greatest pattern area falls between 15 to 25 square inches.
A = 4 when greatest pattern area falls between 11 to 15 square inches.
A = 5 when greatest pattern area falls between 9 to 11 square inches.
A = 6 when greatest pattern area falls between 6 to 9 square inches.
A = 7 when greatest pattern area falls up to 6 square inches.

Table 1A.—Values of A for Copper Blocks

A = 1 for areas of 25 square inches and up.
A = 2 for areas of 15 to 25 square inches.
A = 3 for areas of 11 to 15 square inches.

Table 2.—Cores

Class	Decimal Hours
* A	0.005
B	0.014
C	0.026
D	0.062

* A-D. See Core Classification.

Application:

This formula applies to all molding of alloy castings done on the bench in flasks up to 18 by 14 by 8 inches with or without frames as done in *O*-4 at the present time.

Analysis:

Tools and equipment needed are bottom boards, molding boards, flasks, riddle, shovel, molding sand, patterns, parting sand, peen and rammers, strike bar, venting pins, eore glue, reinforcing nails, water and brushes, gater, slicks, drawing and rapping tools, sprue and riser cutters, cores, bellows, compressed air, graphite, weights, gate patterns, frames, match, file, and iron hook for shake out.

Jobs are put in work by production clerk by sending tag to pattern stores. Pattern keeper draws patterns and core boxes and delivers them. Group leader assigns jobs to each molder. Each molder gets his own eores.

Sand is brought to molders by laborer when needed. Laborer removes finished castings to band saws. Each molder pours and shakes out his own flasks and mixes his own sand.

Ten per cent of additional-piece time is allowed in first-piece time to cover time spent by molder in receiving instructions and the time spent getting equipment ready and determining the best way to do the job.

Two sprue holes are allowed per mold. Table of *A* takes care of the number of different patterns sharing mold constant. In order to make the most standard time, the molder must have this flask as full as possible.

Frames are used whenever the pattern is so large that the regular cope or drag does not leave a deep enough section of sand. The sand may be fairly thin if casting section is small and cools rapidly, but for casting sections of say 15 square inches, at least 3 inches of sand should be between the metal and the bottom board in the drag. In the cope, the sand must be high enough to provide sufficient head in the risers to feed in metal to take care of cooling shrinkage. Here again, the height necessary depends on the size of the casting. In general, the larger the part of the casting in the eope, the higher must be the riser. Alloys 1 and 6 have greater shrinkage than the other alloys commonly used and for this reason must be provided with more generous risers.

Reinforcing with nails is necessary when patterns have narrow sections, pockets, etc., or are very straight. Holes in patterns and weak edges are also reinforced.

No scrapped castings are to receive a standard-time value. They are considered to be made on the molder's own time. For this reason and to care for fatigue and the more than usual unavoidable delays to which a molder is subjected, an allowance of 30 per cent is given.

It is recognized that it takes longer to pour copper than the other alloys because it is necessary to test the condition of each furnace charge and to cover over sprue and riser holes with dry sand and also because, in the majority of cases, more than two sprues and risers are needed. On the other hand, no copper jobs have thin intricate sections and there is not the amount of patching and dressing necessary that there is in other more complicated work. At the same time, copper jobs are considered to fall into the simple

or the medium classification, according to the nature of the parting line, although the time allowed for patching and dressing is greater than is actually necessary. These two conditions offset each other so that the total time per casting will be given by the same formula that is used in other cases.

By copper blocks is meant heavy solid "chunks" of copper. Due to the great cooling shrinkage of copper, it is necessary to have large risers on top of each "chunk." This does not leave as much room for other patterns as there is when these risers are not used. The values of A given in the table for copper blocks are to be used whenever the casting has a large solid section. Many of these blocks must be made in the cope to insure a smooth surface, and in these cases care must be taken to allow time for adding a frame.

Plain cylindrical castings taking a plain cylindrical core in the center are made from a split pattern. In this case, the total length of the parting line is taken to be the length of the parting line of one-half of the pattern only. This is because these are very simple patterns and require very little or no patching. Using the actual total length of the parting line would give a patching time much greater than that actually required.

Chills are to be considered as Class C cores. Care should be used in determining values of A when chills are used to allow the greater area as determined with the chills in place.

Only castings which appear on the shipping report of the brass foundry will be paid for. This eliminates the problem of keeping a record of scrap. First-piece time will be allowed every time a job is marked as finished on the shipping report.

Complex jobs are largely carbon brush holders. Here the parting line is very irregular and the draw hard. An additional 10 per cent is allowed on all these jobs to care for excess patching which may be necessary. Most of these patterns are old and warped, making the draw additionally difficult. Except where a special match board is used, it will be considered that only one is done in a flask. Only a very skilled molder can put two in a flask and then only after he has worked the job for some time. When a match board is used, two patterns may be easily made in one flask. In this case, preparation time is not allowed on the first piece. If only one pattern is ordered for a job with two patterns on one match board, only one pattern will be used. The worker should not be penalized for this, and a special time value should be set for this condition. All complex patterns are considered to be made in one piece.

Pattern Classification:

Simple: Simple edges, not numerous, thick sections, parting line in one plane.

Medium: Several edges, ribs, etc., thin sections or pockets not deep but requiring reinforcing, parting line not in one plane.

Complex: Many edges, ribs, projections, hollows, etc., thin sections, deep and narrow sections requiring reinforcing, parting line very irregular, complicated cope making a difficult draw. Most brush holders fall in this class.

Core Classification:

A: Simple cylindrical cores and other small cores where no filing or fitting is necessary.

B: Cores having few, if any, projections, taking a slight smoothing of the edges before placing.

C: Cores having projections, thin sections, etc., requiring venting and fitting into place.

D: Large and complicated cores, or cores which must be held in place by nails to prevent floating.

Procedure:

Place molding board or match, place patterns, place drag, shake on parting sand, fill riddle, riddle, peen around pattern with fingers, fill drag, peen, refill drag, ram, strike, turn, remove molding board or match, prepare drag for cope, place cope, lay in upper halves of patterns if any, reinforce if necessary, shake on parting sand, fill riddle, riddle, fill cope, peen, refill cope, ram, strike, vent, place molding board, draw cope, gate cope and drag, cut sprue hole and riser, moisten pattern edges, draw patterns, repair cope and drag, file and place cores if any, place drag on floor, stand cope on edge, finish sprue holes on top, place cope on drag, place on weight, prepare for next mold, pour, remove weight, shake out flask and stack, inspect and remove casting, wet and mix sand.

Time Studies

Study Number	Date	Taken by
S-1	10–2–24	H. B. M.
S-2	10–2–24	"
S-3	10–3–24	"
S-4	10–3–24	"
S-5	10–3–24	"
S-6	10–3–24	"
S-7	10–6–24	"
S-8	10–6–24	"
S-9	10–7–24	"
S-10	10–9–24	"
S-11	10–10–24	"
S-12	10–13–24	"

Also miscellaneous short studies covering pouring, shake out, and first-piece time.

Table of Detail Values

Symbol	Operation Description	Reference	Standard Time
A	Place match or molding board on bench	*S*-6	0.0020
B	Place drag	*S*-2-4	0.0032
C	Parting sand	*S*-1-6	0.0026
D	Fill riddle	*S*-10-11	0.0032
E	Riddle	*S*-5	0.0070
F	Fill drag (or cope)	*S*-2	0.0046
G	Peen	*S*-4-3	0.0092
H	Refill drag (or cope)	*S*-4	0.0040
I	Ram	*S*-2-10	0.0078
J	Strike	*S*-7	0.0044
K	Place bottom board	*S*-2-10-11	0.0042

TABLE OF DETAIL VALUES.—(*Continued*)

Symbol	Operation Description	Reference	Standard Time
L	Turn	*S*-3-8	0.0026
M	Remove match	*S*-1-6	0.0034
N	Place cope	*S*-12	0.0057
O	Cut and finish sprue hole complete	*S*-3	0.0178
P	Stand cope on edge and remove molding board	*S*-2	0.0034
Q	Place drag on floor	*S*-1	0.0044
R	Place cope on drag	*S*-1-3-9	0.0062
S	Prepare for next	*S*-1	0.0027
T	Place on weight	*S*-2-8	0.0038
U	Place frame	*S*-5-6	0.0022
V	Fill frame	*S*-5-6	0.0036
W	Gate complete	*S*-12	0.0628
X	Peen with fingers	See Pattern Classification Table	
Y	Lay pattern in place	See Pattern Classification Table	
Z	Prepare drag	See Curves *C-C* lines	
A'	Reinforce	Simple and medium 0.0150 Complex 0.0500	
B'	Draw cope	See Pattern Classification Table	
C'	Repair cope	See Curves *C-C* lines	
D'	Repair drag	See Curves *C-C* lines	
E'	Get core and scrape	See Core Classification Table	
F'	Place eores	See Core Classification Table	
G'	Vent	See Core Classification Table	
H'	Moisten edges	See Curves *C-C* lines	
I'	Shellac core	See Core Classification Table	
K'	Place upper pattern	Sec Pattern Classification Table	
L'	Draw upper part	See Pattern Classification Table	
As	Remove weight		0.0036
Bs	Inspect and remove casting		0.0096
Cs	Shake out and stack flask		0.0122
Ds	Wet per flask		0.0104
Es	Shovel per flask		0.0217
Af	Walk to pattern rack and return		0.0150
Bf	Select job		0.0200
Cf	Get cores from core room		0.0750
Df	Return job to pattern rack		0.0150

PATTERN CLASSIFICATION TABLE

Operation	Simple	Medium	Complex
Lay pattern in place	0.0040	0.0065	0.0065
Draw cope	0.0040	0.0055	0.0170
Draw pattern (includes rap)	0.0052	0.0109	0.0283
Vent	......	......	0.0087
Finger peen (cope and drag)	0.0025	0.0090	0.0188
Wait for help	......	0.0065	0.0130
Total	0.0157	0.0384	0.0923

CORE CLASSIFICATION TABLE

Operation	A	B	C	D
File core	......	0.0079	0.0090	Selected
Place core	0.0050	0.0060	0.0081	from
Vent core seat	......	......	0.0091	totals
Total	0.0050	0.0139	0.0262	0.0625

Synthesis:

$B + 2C + 2D + 2E + 2F + 2G + 2H + 2I + 2J + 2K + L + N + 2O + P + Q + R + S + T + W$ = 0.0032 + 0.0052 + 0.0064 + 0.0140 + 0.0092 + 0.0184 + 0.0080 + 0.0156 + 0.0088 + 0.0084 + 0.0026 + 0.0057 + 0.0356 + 0.0034 + 0.0044 + 0.0062 + 0.0027 + 0.0038 + 0.0628 = 0.2244 = constant per mold to make.

$As + Bs + Cs + Ds + Es$ = 0.0036 + 0.0096 + 0.0122 + 0.0104 + 0.0217 = 0.0575 = constant per mold to shake out.

(Prepare to pour + 3 × pour + 2 × move + return to bench) ÷ 3 = (0.0145 + 3 × 0.0038 + 2 × 0.0031 + 0.0096) ÷ 3 = 0.0140 = constant per mold to pour.

$A + M$ = 0.0020 + 0.0034 = 0.0054 + constant per match = constant per mold for medium patterns.

0.2244 + 0.0575 + 0.0140 = 0.2959 = constant per simple mold.

0.2244 + 0.0575 + 0.0140 + 0.0054 = 0.3013 = constant per medium mold.

$G + H + U + V$ = 0.0092 + 0.0040 + 0.0022 + 0.0036 = 0.0190 = constant per frame.

$Af + Bf + Df$ = 0.0150 + 0.0200 + 0.0150 = 0.0500 = constant for simple first piece.

$Af + Bf + Df + D + E + G + H + I + J + K + L + U + V$ = 0.0150 + 0.0200 + 0.0150 + 0.0032 + 0.0070 + 0.0092 + 0.0040 + 0.0078 + 0.0044 + 0.0042 + 0.0026 + 0.0022 + 0.0036 = 0.1000 = constant for-medium first piece.

$Af + Bf + Cf + Df + D + E + G + H + I + J + K + L + U + V$ = 0.0150 + 0.0200 + 0.0750 + 0.0150 + 0.0032 + 0.0070 + 0.0092 + 0.0040 + 0.0078 + 0.0044 + 0.0042 + 0.0026 + 0.0022 + 0.0036 = 0.1750 = constant for complex first piece.

Inspection:

Castings are inspected to see that they are as nearly perfect as is consistent with foundry practice. Castings must be filled out in every part and have no sand holes, blow holes, or sections out of place due to washed sand or cores.

Payment:

Standard-time group plan.

Approved:

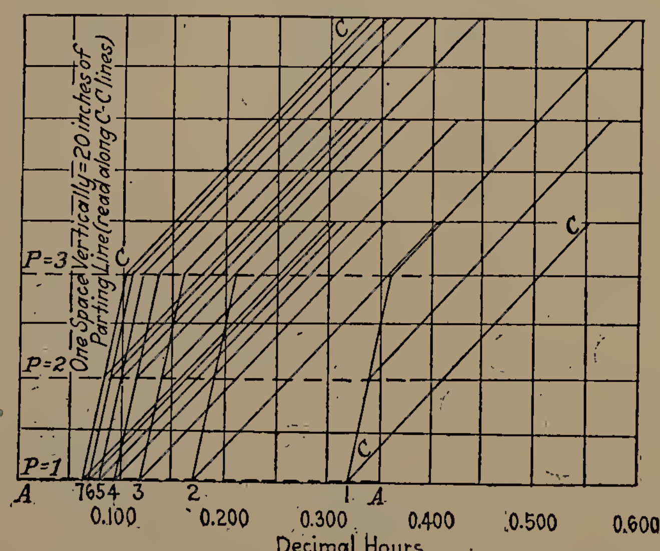
Time-study Supervisor　　　　Time-study Department

Core Table	
Class	Dec. Hrs.
A	0.005
B	0.014
C	0.026
D	0.062

$$\text{Standard Time} = \frac{0.2959}{A} + 0.00234C + 0.0207P + NB + R$$

A—See Table of "A" below.
B—See Core Table.
C—Total length of parting line in inches.
N—Number of cores.
P—Number of parts of pattern.
R—0.0150 where reinforcing is necessary.

Curve 1
Bench Molding—Simple Pattern
Simple Flask—up to 18″ × 14″ × 8″
Formula 0-4 #7 Nov. 15, 1924
Approved: *D. W. Milton*



Add 0.019 Hours per Frame.

Greatest Pattern Area	A
50 sq. in. and up.....	1
25 sq. in. to 50 sq. in.	2
15 sq. in. to 25 sq. in.	3
11 sq. in. to 15 sq. in.	4
9 sq. in. to 11 sq. in.	5
6 sq. in. to 9 sq. in.	6
Up to 6 sq. in........	7

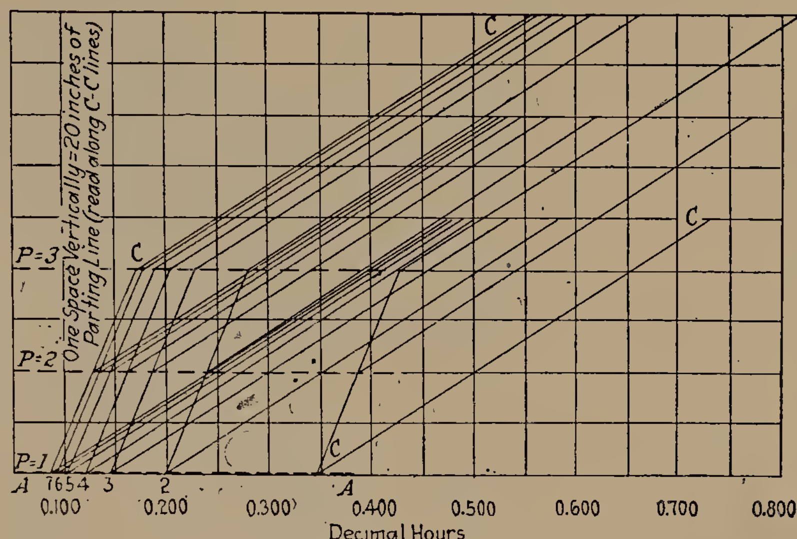
Curve 1.

Core Table	
Class	Dec. Hrs.
A	0.005
B	0.014
C	0.026
D	0.062

$$\text{Standard Time} = \frac{0.3013}{A} + 0.00384C + 0.0434P + NB + R$$

A—See Table of "A" below.
B—See Core Table.
C—Total length of parting line in inches.
N—Number of cores.
P—Number of parts of pattern.
R—0.015 where reinforcing is necessary.

CURVE 2
Bench Molding—Medium Pattern
Simple Flask—up to 18″ × 14″ × 8″
Formula 0-4 #7 Nov. 15, 1924
Approved: *D. W. Milton*



Add 0.019 Hours per Frame

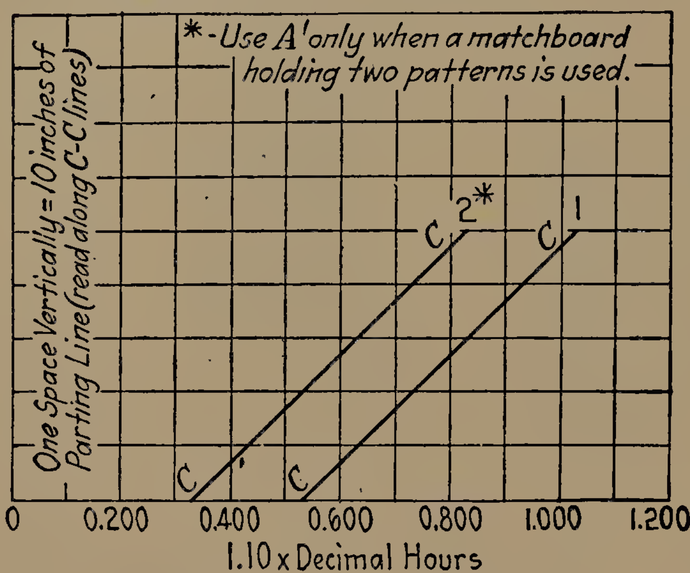
Greatest Pattern Area	A
50 sq. in. and up.....	1
25 sq. in. to 50 sq. in.	2
15 sq. in. to 25 sq. in.	3
11 sq. in. to 15 sq. in.	4
9 sq. in. to 6 sq. in.	5
6 sq. in. to 9 sq. in.	6
Up to 6 sq. in........	7

CURVE 2.

$$\text{Standard Time} = \left(\frac{0.3936}{A'} + 0.0129C + NB + R'\right) 1.10$$

A′—See write up.
B—See Core Table.
C—Total length of parting line in inches.
N—Number of cores.
R—Use when reinforcing is necessary = 0.0500
—for use with curve = 1.10 × 0.0500 = 0.0550

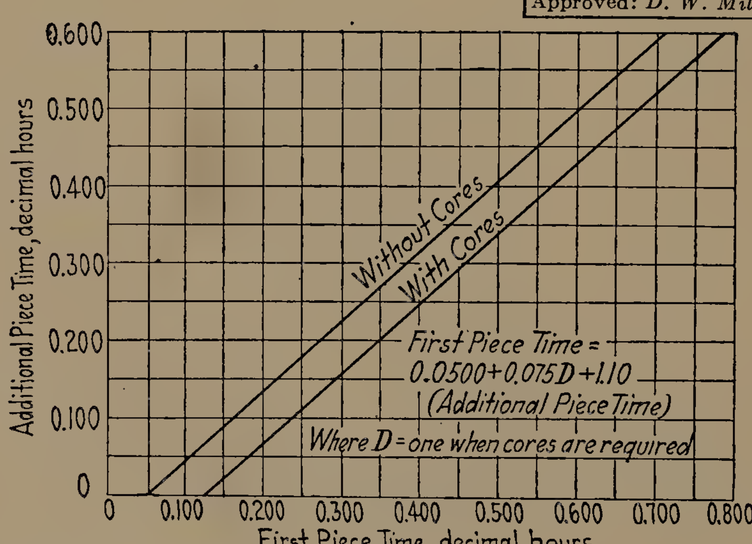
CURVE 3
Bench Molding—Complex Pattern
Simple Flask—up to 18″ × 14″ × 8″
Formula 0-4 #7 Nov. 15, 1924
Approved *D. W. Milton*



Core Table	
Class	Dec. Hrs.
A	0.005
B	0.015
C	0.028
D	0.068

CURVE 3.

CURVE 4
Bench Molding—Simple Pattern
Simple Flask—up to 18″ × 14″ × 8″
Formula 0-4 #7 Nov. 15, 1924
Approved: *D. W. Milton*



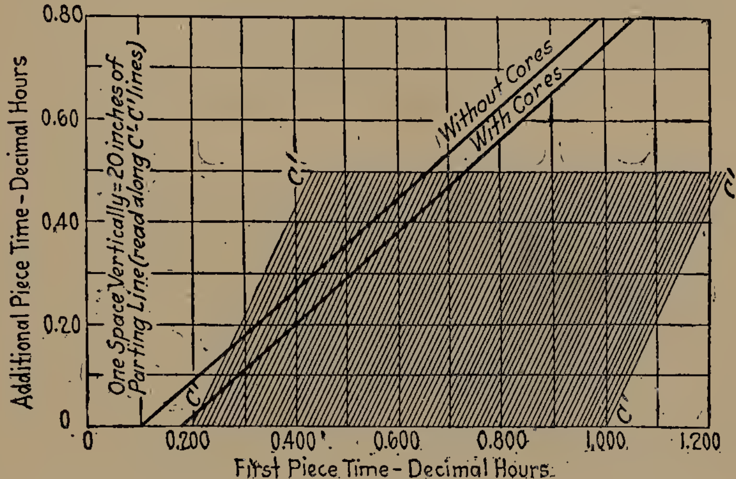
CURVE 4.

First Piece Time = 0.100 + 0.00186C′ + 0.075D + 1.10 (Additional Piece Time)

C′ = Total length of parting line in match in inches

D = One when cores are required

CURVE 5
Bench Molding—Medium Pattern
Simple Flask—up to 18″ × 14″ × 8″
Formula 0-4 #7 Nov. 15, 1924
Approved: *D. W. Milton*

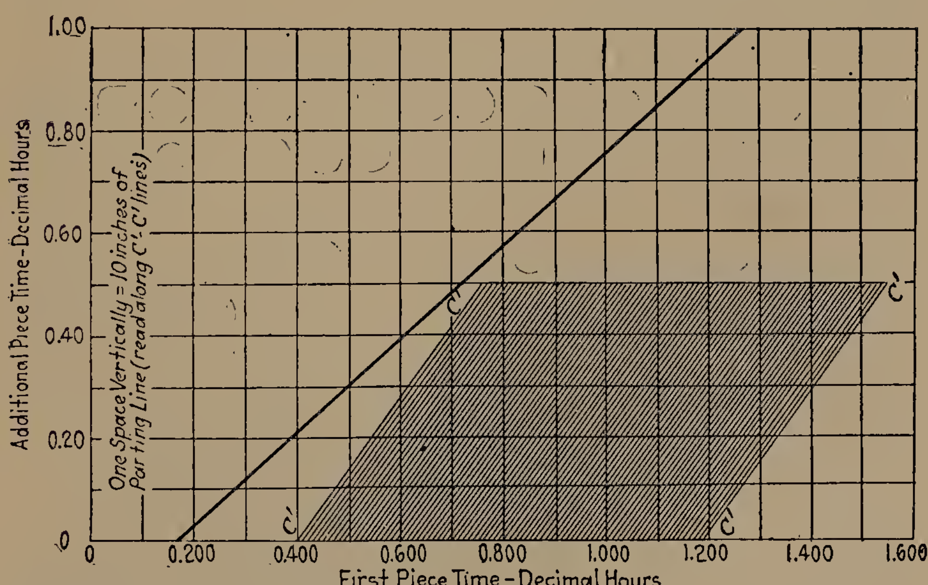


CURVE 5.

First Piece Time = 0.1750 + 0.0077C′ + 1.10 (Additional Piece Time)

C′—Total length of parting line in match in inches

CURVE 6
Bench Molding—Complex Patterns
Simple Flask—up to 18″ × 14″ × 8″
Formula 0-4 #7 Nov. 16, 1924
Approved: *D. W. Milton*



CURVE 6.

CHAPTER XXX

FORMULA FOR STOREROOM

In most lines of manufacturing, the storeroom plays an important part. Figuratively speaking, the storeroom is often the neck of the bottle, for all material is received by the storeroom before it goes to the machine and assembly floors. An efficient shop is dependent on an efficient storeroom.

In spite of the importance of the storeroom, the job of the storeroom attendant is not considered as being high class. What is required of the attendant more than anything else is interest in the work, a good effort, and cooperation with the other storeroom attendants and the operators on the floor. These things are not easily secured from the type of men who are usually employed for storeroom work, especially when their earnings are in no way dependent on what they do.

It has been proved that the best and the easiest way to get a good effort on a job is to connect earnings with effort. Instead of paying a man more money on the day-work basis, he should be given an opportunity to earn more under some good incentive plan. During times of peak prosperity the cry of labor shortage is heard on every hand; but the real difficulty is that full advantage is not yet taken of what labor is available. The proper effort is not obtained from the labor that is employed on such work as storeroom work, material handling, and the like.

The formula example given in this chapter shows how storeroom work can be measured with remarkable accuracy. Previous to the making and applying of this formula, several bonus schemes were tried, but due to the variety of the work and the lack of scientific method of measurement, they proved unsatisfactory.

In storeroom work, output is not directly proportional to effort. If it takes a certain amount of effort to fill a certain sized order, it by no means follows that it will take twice the effort to fill an order twice as large. At first glance, it might seem that first-piece and additional-piece time values should be established,

but several things, such as the clerical work involved in the payroll computations and the difficulty of handling "stock out" cases, render this impracticable.

After the storeroom work had been carefully studied, it was found that under average conditions a 10 per cent increase in effort brought about a 100 per cent increase in output. Earnings should be tied up with effort, and therefore the bonus made is figured as follows:

$$\frac{\text{Time allowed}}{\text{Time taken}} \times 10 = \text{bonus in per cent.}$$

Under this plan, if the time allowed is less than the time taken, no bonus is allowed. If the time allowed is exactly equal to the time taken, a bonus of 10 per cent is paid, and if twice the time taken, a 20 per cent bonus is given. Earnings under this plan have been very consistent through busy times and dull, labor turnover among the storeroom crew has been reduced to almost nothing, and the men are well satisfied.

Formula F-12 No. 8.
Mar. 16, 1925.

Part:

All materials stored in section *F*-12 storeroom.

Operation:

Receive, store, draw out, and deliver material used by section *F*-12. Issue material on requisitions, from other departments, and 5501's. Operations that arise in connection with the above, as mentioned in this formula.

Work Station:

F-12 storeroom.

Allowed Time:

Per unit of apparatus:
$[0.000547A + (0.00246 + \text{Curve 1})B + (0.00639 + \text{Curve 2})C + (0.0683 + \text{Curve 3})D]\ 1.75$,

where A = number of parts small enough to weigh out* (excluding hardware).
B = number of parts, above weighing size, that are stored in bins.†
C = number of parts, weighing 100 pounds or less, that are stacked on the floor.
D = number of parts, weighing over 100 pounds, that are stacked on the floor.

* In general, parts weighing ⅛ pound or less.

† In general, parts weighing over ⅛ pound up to 25 pounds and occupying a space of not more than 1 cubic foot.

Application:

This formula applies to the handling of all material that is received and issued by *F*-12 storeroom under conditions as of Mar. 16, 1925.

Analysis:

Material is handled on:

	Form Number
Issues	3904-*A* and 4566
Foreman's requisitions	1774-*D*
Works delivery to stores or warehouse	5501-*C*
Interworks delivery	1775-*A*
Works credit memorandum	1773-*A*
Works requisitions on storeroom	1772-*C*
Credit slip	3986
Finished-material delivery slip	41

"Issues" are made out by the group leader for all material required from the storeroom; exceptions to this rule are often made with drawing and item material, when the material is drawn on verbal notice alone, from the group leader.

"Foreman's requisitions" cover material required from and by other storerooms and departments, also material sent out for finishes, etc.

"5501's" cover material sent to other storerooms or warehouses for shipping.

"Interworks deliveries" cover material ordered from storeroom by Homewood Works, also material delivered to the storeroom by feeder sections.

"Works credit memorandums" cover material ordered from storeroom by D. & S. Stores.

"Works requisitions on storerooms" cover material delivered to storeroom by other storerooms.

"Credit slips" cover material returned to storeroom from within the department, sueh as surplus, etc.

"Finished-material delivery slips" cover material and parts of apparatus on which work has been done (such as machining and assembling) that is sent to the storeroom by its own section.

The personnel of the storeroom consists of five men, with duties as follows: The stockman supervises the work of the other four men; handles all 5501's and requisitions for material ordered by Homewood Works, D. & S. Stores, and other departments; keeps track of order points and stock-out material; disposes of surplus material and helps the other four men whenever necessary.

The second man stores away all standard material and castings that are delivered to the storeroom.

The third man draws standard material and delivers it to the workmen.

The fourth man receives and issues all drawing and item material and material bought outside; stores it away and makes out requisitions for machining and finishing of the material. He also tends to the window, making small issues of hardware and miscellaneous material for which the workmen go to the storeroom.

The fifth man helps to draw, or store, material; revises order points; and does some trucking, with a hand truck, between other storerooms and

departments, such as, going after material that is wanted in a hurry, or delivering service orders to the shipping department when the electric truck is not available. This trucking should not average more than 25 per cent of one man's time as practically all trucking between departments should be done by an electric truck.

All material is delivered direct to the storeroom, except small quantities that are delivered, by Shop Express, to the section express station and taken from there to the storeroom, by the storeroom help; and small quantities for which the storeroom help goes to other storerooms or departments.

All material is stored in bins or stacked on the floor, depending on its size. Material stored in bins may be either ranked or thrown into the bin, depending again on its size.

As the material is stored, each piece is counted (the small pieces are weighed on calculating scales, as hardware, clips, etc.), and the amount recorded on a lot tag, which is attached to each bin or stock of material.

The locations of the stored material are posted in a card file according to style or stock order numbers, whichever the material may be on.

Material of the same style may be on two or more different storeroom numbers in which case it is stored in separate lots according to the storeroom number. This is done for accounting purposes.

When storing a new lot of material, a certain number of pieces are separated from the rest of the lot by a sheet of heavy paper to mark an order point.

Material is drawn on "issues" presented at the storeroom by the workmen. If the workman wishes to take the material with him, it is drawn at once by the man tending to the window. If the material is not wanted at once, the issue is placed in a basket beside the window and filled in its turn.

Issues are taken from the basket and the locations of the material determined from the card file and marked on the issue.

The material is then drawn, loaded on a truck and delivered to the workmen.

The issue is then signed by the group leader and taken back to the storeroom where it is deposited in a box. The box is emptied each morning and all the receipts and issues of the preceding day are turned in to the ledgerman.

Material that is drawn on 5501's and requisitions from other departments is tagged and piled in a shipping space, in the storeroom, from which it is taken by an electric truck and delivered.

The duties of storing, drawing and delivering standard material to workmen, also of filling 5501's and requisitions from other departments, are covered by established values from time studies. These duties amount to three-fifths of five men's time. The duties of handling drawing and item material and hardware, tending to window, trucking, keeping the storeroom in a clean and neat condition and supervising, were found, by investigation, to amount to two-fifths of the five men's time. This is covered by multiplying the time allowed for handling standard material and requisitions by the factor 1.75, which was arrived at as follows: $5 \div 3 = 1.66$, the number by which the time of three men must be multiplied to equal the time of five men. This was raised to 1.75 to allow time for revising order points and other small, irregular duties.

To the values for storing material has been added 44 per cent; 25 per cent for fatigue and unavoidable delays and 19 per cent for irregular operations such as clearing bins, marking order points, checking with stockman and ledger, untying sacks of material and cleaning up around the bin after storing material.

To the values for drawing and delivering material has been added 37 per cent; 25 per cent for fatigue and unavoidable delays and 12 per cent for irregular operations such as checking with stockman, looking up material due to errors in records, waiting for elevator, eollecting empty pans, getting different size trucks, and carrying upstairs small quantities of material that are wanted in a hurry.

These percentages of 19 and 12 are the actual percentages of time, over which the studies were taken, that were taken up by these irregularities.

The average number of pieces on one receipt, or issue, varies with the size of the part. These averages were determined by averaging a number of receipts and issues over different periods of time within the past 3 months, at which time the activity in the section was about 80 per cent normal; therefore the averages found, being 80 per cent normal, were raised to 100 per cent.

Example: 18,369 ÷ 36 = 510. 510 = 80 per cent. 100 per cent = 600 approximate, where 18,369 equals the number of pieces, small enough to be weighed on calculating scale, that were ordered on 36 issues. These issues were taken from dates in the first, middle, and last parts of different months.

Other averages adopted as a result of investigations follow:

Average number of issues per load.	2
Average number of items per issue.	2
Average number of pans per load.	2

These three averages do not apply to parts weighing over 100 pounds per piece, in which case the average is one item per load.

Procedure:

For small parts that are weighed on calculating scale: Get receipt from material and check location (*A*); move material to scale (*C*); weigh (*D*); store after weighing (*E*); post amount on tag and location on receipt (*I*); post location to card file; O.K. and put away receipt (*J*); get issue from basket (*K*); check location (*L*); move truck (*M*); get empty pan and set on truck (*O*); get scale pan and take to material (*Aa*); fill scale pan with material (*Ba*); carry pan of material to scale (*Ca*); weigh (*D*); dump material into pan after weighing (*Da*); deliver material to floor (*S*); unload pan of material (*T*); get issue signed by group leader (*W*); return to storeroom (*X*); put issue away (*Y*).

For parts above weighing size that are stored in bins: Get receipt from material and check location (*A*); move material to location (*B*); store in bin (*F*); post amount on tag and location on receipt (*I*); post location to card file, O.K. and put away receipt (*J*); get issue from basket (*K*); check location (*L*); move truck to location (*M*); get empty pan and set on truck (*O*); draw material from bin (*P*); deliver to floor (*S*); unload pan of material (*T*); get issue signed by group leader (*W*); return to storeroom (*X*); put issue away (*Y*).

For parts stacked on the floor, weighing 100 pounds or less, also for large parts stored in bins, such as transformers, assembled relays, and shafts, the

procedure is the same as above except the material is not delivered in pans, but is stacked on the truck (*Q*) and stacked on the floor or bench when delivered to workmen (*U*).

For parts stacked on the floor, weighing over 100 pounds each, the procedure is the same as in the preceding paragraph except that moving material to storing location, stacking, loading, delivering and unloading requires two men.

TABLE OF DETAIL VALUES

Symbol	Operation Description	Reference	Time Allowed
A	Get receipt from material and check card file for location	See Master Sheets	0.0735
B	Move material to location	"	0.0212
C	Move material to scale	"	0.0173
D	Weigh (per piece)	"	0.00004
E	Store after weighing (per piece)	"	0.00007
F	Store material in bin (per piece)	"	½ Curve 1
G	Stack material on floor (per piece) (pieces weighing 100 pounds or less)	"	⅓ Curve 2
H	Stack material on floor (per piece) (pieces weighing over 100 pounds)	"	⅓ Curve 3
I	Post amount on tag and location on receipt	"	0.0144
J	Post location to card file; O.K. and put away receipt	"	0.0331
K	Get issue from basket	"	0.0206
L	Check location (per item)	"	0.0188
M	Move truck to first material location	"	0.0212
N	Move truck from one to another location	"	0.0070
O	Get empty pan and set on truck	"	0.0050
P	Draw material from bin (per piece)	"	½ Curve 1
Q	Load material from floor (per piece) (pieces weighing 100 pounds or less)	"	⅓ Curve 2
R	Load material from floor (per piece) (pieces weighing over 100 pounds)	"	⅓ Curve 3
S	Deliver material to floor	"	0.0575
T	Unload material (per pan)	"	0.0082
U	Unload material (per piece 100 pounds or less)	"	⅓ Curve 2
V	Unload material (per piece above 100 pounds)	"	⅓ Curve 3
W	Get issue signed by group leader	"	0.0370
X	Return to storeroom	"	0.0342
Y	Put issue away	"	0.0164
Z	Fill 5501 or requisition from another department (each)	"	0.0426
Aa	Get scale pan and take to material	"	0.0069
Ba	Fill scale pan with material (per piece)	"	0.000012
Ca	Carry pan of material to scale	"	0.0040
Da	Dump material into pan after weighing	"	0.0082
Ex	Average number of pieces on one receipt		
Wx	Average number of pieces on one issue		

TABLE OF DETAIL VALUES.—(*Continued*)

	Ex	*Wx*
For parts that are weighed out....................	2,000	600
For parts, above weighing size, stored in bins	300	80
For parts, weighing 100 pounds or less, stacked on floor	50	40
For parts, weighing over 100 pounds, stacked on floor..	13	6

Synthesis:

Curves.—Curves were obtained by plotting the weight per piece against the time per operation.

Curve 1 was obtained by first plotting separate curves for storing and drawing material stored in bins. Since the difference between these curves was small, one curve was drawn as an average of both operations and could be used for either. As this curve would be used twice in the formula, it was doubled to make the final curve.

Curves 2 and 3 were obtained in the same way, by first drawing separate curves for stacking, loading on truck and unloading or stacking again upon delivery to workmen. These curves were then averaged into one curve and this curve tripled to make the final curve. Each curve includes 40 per cent per operation, which is an average of the 44 per cent and 37 per cent added to the other values as mentioned before.

Time per piece for handling small parts that are weighed on calculating scales:

$$\left(\frac{A+C}{Ex} + D + E + \frac{I+J}{Ex} + \frac{K+4L+M+2O+4Aa}{2Wx} + 2Ba + \frac{4Ca}{2Wx} + D + \frac{4Da+S+2T+W+X+Y}{2Wx}\right)1.75 = \left(\frac{A+C+I+J}{Ex} + \frac{K+4L+M+2O+4Aa+4Ca+4Da+S+2T+W+X+Y}{2Wx} + 2D + E + 2Ba\right)1.75 = \left(\frac{0.0735+0.0173+0.0144+0.0331}{2{,}000} + \frac{0.0206+(4\times 0.0188)+0.0212+(2\times 0.0050)+(4\times 0.0069)+(4\times 0.0040)+(4\times 0.0082)+0.0575+(2\times 0.0082)+0.0370+0.0342+0.0164}{2\times 600} + (2\times 0.00004)+0.00007+(2\times 0.000012)\right)1.75 = \left(\frac{0.1383}{2{,}000} + \frac{0.3649}{1{,}200} + 0.000184\right)1.75 = (0.000069+0.000304+0.000174)\,1.75 = 0.000547\times 1.75.$$

Time per piece for handling parts stored in bins:

$$\left(\frac{A+B}{Ex} + F + \frac{I+J}{Ex} + \frac{K+4L+M+3N+2O}{2Wx} + P + \frac{S+2T+W+X+Y}{2Wx}\right)1.75 = \left(\frac{A+B+I+J}{Ex} + \right.$$

$$\frac{K + 4L + M + 3N + 2O + S + 2T + W + X + Y}{2Wx} + F + P\Big) 1.75 =$$

$$\Big(\frac{0.0735 + 0.0212 + 0.0144 + 0.0331}{300} +$$

$$\frac{0.0206 + (4 \times 0.0188) + 0.0212 + (3 \times 0.0070) + (2 \times 0.0050) + 0.0575 + (2 \times 0.0082) + 0.0370 + 0.0342 + 0.0164}{2 \times 80} +$$

$$2 \times \tfrac{1}{2} \text{ Curve } 1\Big) 1.75 = \Big(\frac{0.1422}{300} + \frac{0.3095}{160} + \text{Curve } 1\Big) 1.75 = \Big(0.00246 + \text{Curve } 1\Big) 1.75.$$

Time per piece for handling parts stacked on floor, weighing 100 pounds or less:

$$\Big(\frac{A + B}{Ex} + G + \frac{I + J}{Ex} + \frac{K + 4L + M + 3N}{2Wx} + Q + \frac{S}{2Wx} + U + \frac{W + X + Y}{2Wx}\Big) 1.75 = \Big(\frac{A + B + I + J}{Ex} +$$

$$\frac{K + 4L + M + 3N + S + W + X + Y}{2Wx} + G + Q + U\Big) 1.75 =$$

$$\Big(\frac{0.0735 + 0.0212 + 0.0144 + 0.0331}{50} + \frac{0.0206 + (4 \times 0.0188) + 0.0212 + (3 \times 0.0070) + 0.0575 + 0.0370 + 0.0342 + 0.0164}{2 \times 40} +$$

$$3 \times \tfrac{1}{3} \text{ Curve } 2\Big) 1.75 = \Big(\frac{0.1422}{50} + \frac{0.2831}{80} + \text{Curve } 2\Big) 1.75 = \Big(0.00639 + \text{Curve } 2\Big) 1.75.$$

Time per piece for handling parts stacked on floor, weighing over 100 pounds:

$$\Big(\frac{A + 2B}{Ex} + H + \frac{I + J}{Ex} + \frac{K + L + M}{Wx} + R + \frac{2S}{Wx} + V + \frac{2W + 2X + Y}{Wx}\Big) 1.75 = \Big(\frac{A + 2B + I + J}{Ex} +$$

$$\frac{K + L + M + 2S + 2W + 2X + Y}{Wx} + H + R + V\Big) 1.75 =$$

$$\Big(\frac{0.0735 + (2 \times 0.0212) + 0.0144 + 0.0331}{13} + \frac{0.0206 + 0.0188 + 0.0212 + (2 \times 0.0575) + (2 \times 0.0370) + (2 \times 0.0342) + 0.0164}{6} +$$

$$3 \times \tfrac{1}{3} \text{ Curve } 3\Big) 1.75 = \Big(\frac{0.1634}{13} + \frac{3344}{6} + \text{Curve } 3\Big) 1.75 = \Big(0.0126 + 0.0557 + \text{Curve } 3\Big) 1.75 = \Big(0.0683 + \text{Curve } 3\Big) 1.75.$$

Payment:

Special day-work bonus group plan.

To the time allowed for the number of pieces of apparatus shipped is added the time allowed for filling 5501's and requisitions for other depart-

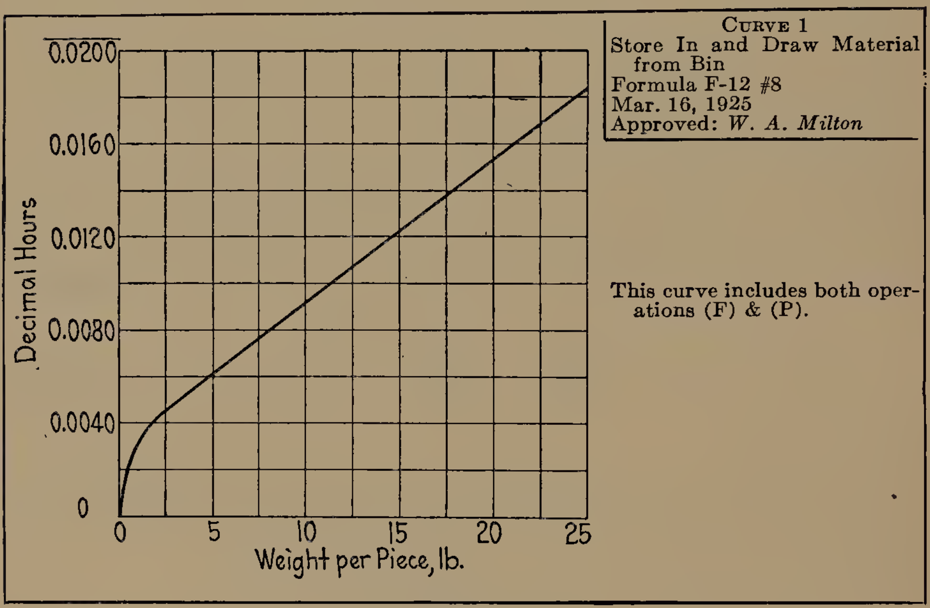
ments at 0.10 each. These 5501's and requisitions are to be turned over to the cost department each day, to be summed up at the end f the pay period and upon the approval of the supervisor of production, figured in the group earnings.

The time allowed is divided by the time taken and the result multiplied by the controlling factor (0.10) to determine the bonus percentage which is added to the hourly rate of each member of the group.

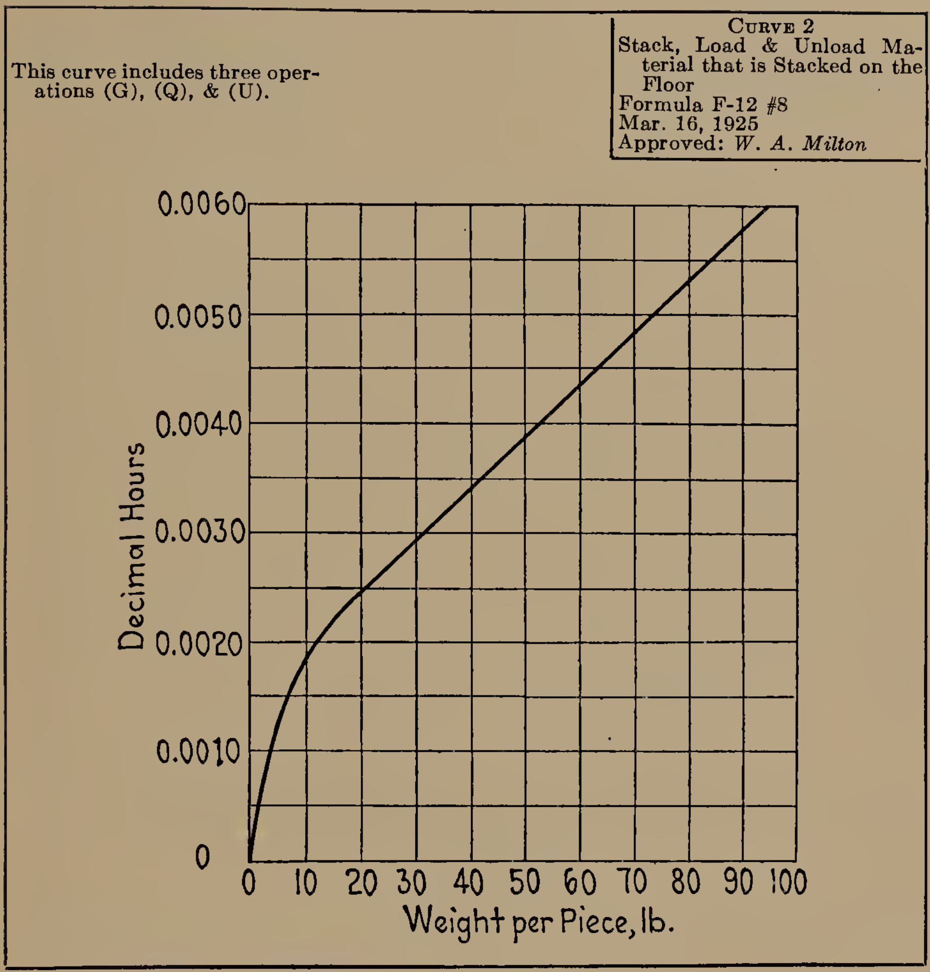
Approved:

Time-study Supervisor

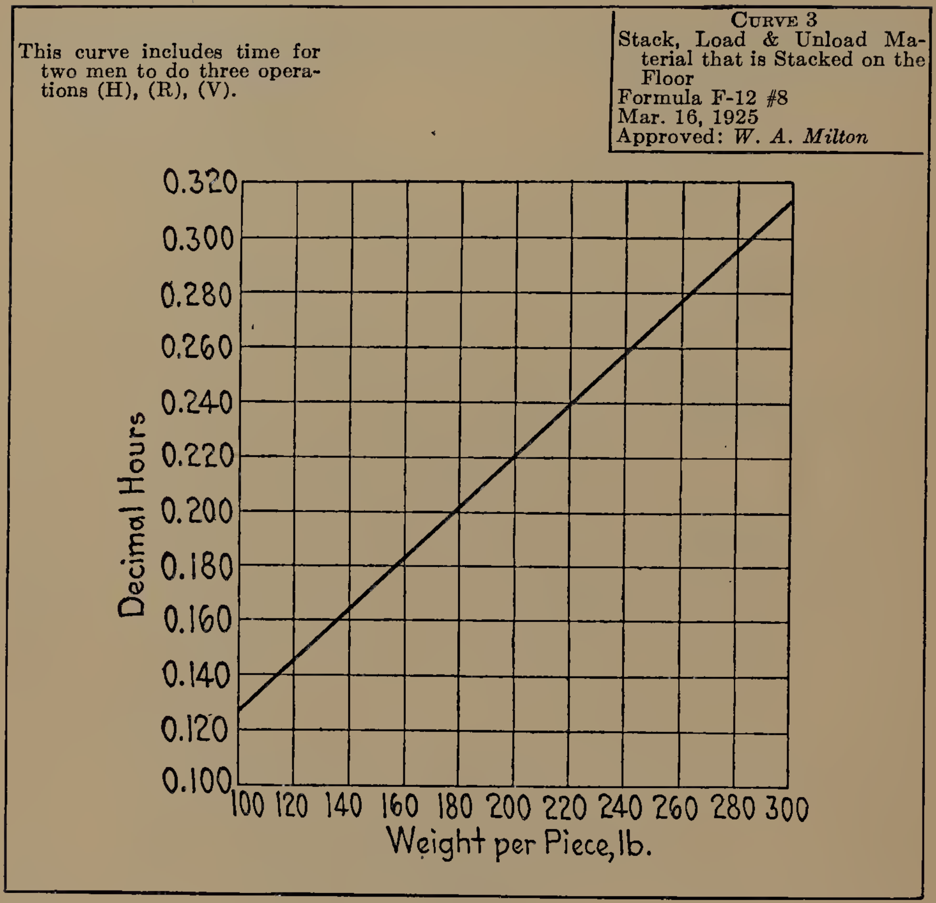
Time-study Department



Curve 1.


This curve includes three operations (G), (Q), & (U).
CURVE 2
Stack, Load & Unload Material that is Stacked on the Floor
Formula F-12 #8
Mar. 16, 1925
Approved: W. A. Milton
Decimal Hours
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0
0 10 20 30 40 50 60 70 80 90 100
Weight per Piece, lb.

CURVE 2.


This curve includes time for two men to do three operations (H), (R), (V).
CURVE 3
Stack, Load & Unload Material that is Stacked on the Floor
Formula F-12 #8
Mar. 16, 1925
Approved: *W. A. Milton*
Decimal Hours
0.320
0.300
0.280
0.260
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
100 120 140 160 180 200 220 240 260 280 300
Weight per Piece, lb.

CURVE 3.

CHAPTER XXXI

FORMULA FOR WINDING A.C. FIELD COILS

In most factories engaged in the manufacture of electrical apparatus, the making of various kinds of coils comprises a large part of the work. These coils vary in the number of turns, size of wire, shape of wire, size of coil, and the like, according to the rating, design, and purpose of the apparatus with which they are to be used. Due to these variable characteristics, it is difficult to establish accurate and consistent time allowances by comparison. In plants, however, where the number of jobs is large and scarcely two alike, it is obviously impractical to time study each individual job. The majority of time allowances, therefore, when established by estimate and comparison, are largely guesses based, of course, on some other similar jobs. Even though the estimator has a good knowledge of the work, actual practice has proved this method to be unsatisfactory from almost any viewpoint.

The formula method has solved the difficulty in establishing time values on this kind of work, as it has before, wherever it has been applied. The coil-winding formula given in this chapter as an example has been in use for several years and proved its merits beyond question. Previous to the application of this particular formula, the operators who were engaged on the work were continually complaining about the inconsistency of time values. Since its application, complaints of this kind are very rare. The time saved in establishing time values, the advantages in costing, and the feeling of satisfaction enjoyed by both workers and supervisors, brought about by the application of this formula, have justified many times over the time spent in its compilation.

Whenever there is a chance that a formula may be wrongly applied, a complete set of instructions on just how each term should be handled should accompany the formula. In the case of the formula here given, a number of terms are used which are peculiar to coil winding alone. In order that no ambiguity

might exist, a set of instructions has been made up. They are made up in a similar form to the working sheets, and blueprinted copies together with the working copies of the formula are kept in the formula book of the routine man.

Formula E-2 No. 7.
Sept. 15, 1920.

Part:

A.C. field coils.

Operation:

Wind.

Work Station:

No. 4 winding head.

Allowed Time:

Straight-up Coils.—$0.1430 + 0.0008I + 0.0151L_1 + 0.0025M + 0.0117N + 0.0800P + Q + S + 0.0057W + Z +$ Curve 1 $+ L$ (Curve 2) $+ L_2$ (Curve 3) $+$ Curve 5 $+ T$ (Curve 6).

Two-half Coils.—$0.2680 + 0.0143F + 0.0008I + 0.0151(L_1 + L_2 - 2) + 0.0025M + 0.0117N + 0.0800P + Q + S + 0.0057W +$ Curve 1 $+ (L_1 + L_2)$ (Curve 2) $+ (L_1 + L_2 - 4)$ (Curve 3) $+$ Curve 4 $+$ Curve 5 $+ T$ (Curve 6),

where F = number of cambric ties used to tie two halves together.
I = number of inches of wire taped.
L = number of layers for straight up coils.
L_1 = number of layers in first half of two-half coils.
L_2 = number of layers in second half of two-half coils.
M = number of plain lugs.
N = number of lugs drawn with loop strings.
P = number of short-circuits to be made.
Q = See Table I.
S = See Table II.
T = Total number of turns.
W = number of clamps minus one used on first turn.
Z = See Table III.

Table I.—Miscellaneous Values

Block coil before removing, for coils over 100 pounds	0.0161
Make air ducts per coil	0.0752
Make insulating short circuit	0.0382

Table II.—Take Coil to Inspector

Up to 21 pounds, 3 per trip	0.0050
21 to 41 pounds, 2 per trip	0.0075
41 to 75 pounds, 1 per trip	0.0150
Over 75 pounds, taken on truck	0.0638

TABLE III.—PLACE STRAP-COPPER LEADS

Plain lead, per lead	0.1050
Special lead, per lead	0.2096

Application:

This formula applies to all a.c. revolving field coils wound on rectangular center blocks under the following conditions. Square wire up to 0.229 inch; wire wound flat having vertical dimension up to 0.229 inch; wire wound on edge having vertical dimension up to 0.350 inch; weight of coil not over 325 pounds; and perimeter of center block not over 60 inches.

Analysis:

Tools and accessories needed are scissors, knife, brush and can for bakelite and varnish, solder iron, solder ladles, rawhide mallet, monkey wrench, pliers, wire cutters, and drifting and pounding blocks.

Materials and supplies needed are fuller board, fish paper and mica combination strips, asbestos paper, tinned sheet copper for short-circuits and leads, paraffin wax, cambric, cotton tape, drilling, string, bakelite, and any other material which may be specified.

A.c. field coils are divided into two general classes, *viz.*, straight-up and two-part coils. Straight-up coils are those that are wound continuously with the starting lead brought out at the bottom from the first turn and the finish lead brought out at the top from the last turn. Two-part coils are those which have both leads brought out at the top. Bringing both leads out at the top is accomplished by winding two coils and connecting the start of one to the start of the other thus making one coil with both leads coming from the top. Coils are wound in two parts for design reasons. When two-part coils are required, it will be specified in the winding information with instructions as to the number of turns in each part.

Each operator secures his own supplies from the storeroom and his mold duct blocks and spacers from the mold room. Five per cent is allowed to take care of time so spent.

The operator writes an order for his wire and gives it to the wireman. The wireman brings wire as ordered to the operator. The time required to change a reel of wire and to weld the new wire to the old was found by time study to be 0.1400 hour. The average weight of a reel of wire may be taken as 100 pounds. This is slightly less than the weight of a full reel but is compensated for by stubs. The time for making the change complete is distributed to each coil according to weight by adding 0.0014 per pound to the allowed time.

The instruction sheet which accompanies the working sheets of this formula gives in detail the correct method of applying the formula. These instructions should be followed exactly in all cases.

Procedure:

Clean mold, place mold on winding head, place and tighten two nuts, place temporary fuller board on center block, cut and place four fuller-board corners on center block, tie temporary fuller board and corner pieces to center block, remove tension from reel, pull wire up and fasten on mold, wedge or clamp wire, set counter, replace tension on reel, get tape, finish tape first

turn, wind first layer, pound each layer, bakelite each layer, tape last turn, get and place crossover sheet, cut and place fuller board on corners, repeat taping and winding operations until coil is finished, cut and place lug, get and place loop string, cut and draw lug with loop string, cut off end lugs, cut and place fuller board and mica protector, skin wire, emery wire for short circuit, cut and place copper strap and asbestos, take brush and apply soldering paste, make short-circuit connection, get soldering iron, clean soldering iron, solder short-circuit connection, return soldering iron, trim insulation at short-circuit, cut wire and lay aside, move bench aside, remove two nuts, remove side of mold, remove coil, remove center block, remove temporary fuller board, get string, tie one string on corner, write tag, glue and place tag, carry coil to inspectors, place sheet-copper lead complete, go for solder ladles and return solder ladles.

Time Studies

Study Number	Date	Taken by
S-1	1-7- 3-20	G. J. S.
S-2	2-7- 3-20	"
S-3	1-7- 4-20	"
S-4	1-7- 1-20	"
S-5	1-7- 8-20	"
S-6	1-7- 9-20	"
S-7	1-7-10-20	"
S-8	1-7-12-20	"
S-9	1-7-14-20	"
S-10	1-7-15-20	"
S-11	1-7-16-20	"
S-12	1-7-17-20	"
S-13	1-7-18-20	"
S-14	1-7-19-20	"
S-15	1-7-20-20	"
S-16	1-7-21-20	"
S-17	1-7-22-20	"
S-18	1-7-23-20	"
S-19	1-7-24-20	"
S-20	1-7-25-20	"

Table of Detail Operations

Symbol	Operation Description	Time Allowed	Reference
A	Clean sides of mold.	Curve	
B	Place mold on winding head.	Curve	
C	Place and tighten two nuts.	Curve	
D	Place temporary fuller board on center block.	0.0050	*S*-4
E	Cut and placc 4 fuller-board corners on center block	0.0269	*S*-4
F	Tie temporary fuller-board and fuller-board corners to center bloek.	0.0078	*S*-7
G	Clean collar.	Curve	
H	Place and tie collar.	Curve	
I	Take tension off reel.	0.0042	*S*-2

TABLE OF DETAIL OPERATIONS.—(*Continued*)

Symbol	Operation Description	Time Allowed	Reference
J	Pull wire up and lay on mold	0.0066	*S*-6
K	Hold start to mold with clamp or pliers, wedge	0.0057	*S*-7
L	Set counter	0.0050	*S*-3
M	Replace tension on reel	0.0066	*S*-4
N	Get tape to tape turn	0.0029	*S*-3
O	Tape per inch	0.0008	*S*-7
P	Pound per layer	Curve	
Q	Bakelize per layer	Curve	
S	Wind per turn	Curve	
T	Get and place crossover sleeve	0.0051	*S*-1
V	Place one piece of fuller board 0.007 at corner	0.0013	*S*-4
W	Cut one piece of 0.007 fuller board for corner	0.0012	*S*-2
X	Tape crossover on build	0.0073	*S*-6
Y	Get and place one lug	0.0025	*S*-3
Z	Place one loop string	0.0028	*S*-2
*A*1	Cut and draw lug with loop string	0.0076	*S*-3
*B*1	Cut off end of drawn lug	0.0013	*S*-4
*C*1	Cut and place fish paper and mica insulation	0.0064	*S*-5
*D*1	Skin wire	0.0020	*S*-2
*E*1	Cut and place piece of copper strap and asbestos	0.0130	*S*-9
*F*1	Take brush and apply soldering paste	0.0034	*S*-7
*G*1	Make short-circuit connection	0.0136	*S*-11
*H*1	Get soldering iron	0.0061	*S*-10
*I*1	Clean soldering iron	0.0030	*S*-8
*J*1	Solder short-circuit connection	0.0117	*S*-19
*K*1	Return soldering iron	0.0061	*S*-19
*L*1	Trim insulation at short-circuit	0.0043	*S*-7
*M*1	Cut wire and lay aside	0.0035	*S*-9
*O*1	Move bench aside	0.0020	*S*-4
*P*1	Remove string from collar	Curve	
*Q*1	Remove collar and lay aside	Curve	
*R*1	Reverse mold	Curve	
*S*1	Remove two nuts	Curve	
*T*1	Get welder and welding machine	0.0209	*S*-6
*U*1	Make weld	0.0287	*S*-17
*V*1	Remove welding machine	0.0034	*S*-19
*W*1	File weld	0.0080	*S*-14
*X*1	Tape weld	0.0105	*S*-7
*Y*1	Remove side of mold	Curve	
*Z*1	Remove coil	Curve	
*A*2	Remove center block from coil	Curve	
*B*2	Remove temporary fuller board	0.0034	*S*-18
*C*2	Get string	0.0026	*S*-17
*D*2	Tie one string on corner	0.0089	*S*-19
*E*2	Write double tag	0.0230	*S*-6
*G*2	Glue and place tag	0.0061	*S*-7

Table of Detail Operations.—(*Continued*)

Symbol	Operation Description	Time Allowed	Reference
$H2$	Cut and place cambric sleeve	0.0041	S-6
$I2$	Cut and place long cambric ties	0.0065	S-14
$J2$	Fasten ends of cambric ties to side of mold	0.0078	S-12
$K2$	Carry coil to inspectors bench, over 75 pounds	0.0300	S-14
$L2$	Carry coil to inspectors bench, 41 to 75 pounds	0.0150	S-17
$M2$	Carry coil to inspectors bench, 21 to 41 pounds	0.0075	S-19
$N2$	Carry coil to inspectors bench, up to 21 pounds	0.0050	S-8
$O2$	Place fuller board or rope filler to throw crossover	0.0180	S-4
$P2$	Get truck	0.0338	S-7
$Q2$	Place blocks under coil over 100 pounds before removing	0.0161	S-6
$R2$	Place per clamp on first turn	0.0057	S-7
$S2$	Clean duct blocks for one end	0.0060	S-14
$T2$	File edges off spacer	0.0052	S-18
$U2$	Place duct blocks and spacer, one end	0.0110	S-17
$V2$	Drive out duct blocks on one end	0.0102	S-12
$X2$	Emery wire for short-circuit	0.0041	S-3
$Y2$	Cut and place duck to insulate short-circuit	0.0055	S-9
$Z2$	Place sheet-copper lead complete	0.0774	S-10
$A3$	Go for solder ladles	0.0153	S-7
$B3$	Return solder ladles	0.0123	S-12
$C3$	Pull duck over short-circuit with string	0.0331	S-13
$D3$	Tape lead connections and lead, special top	0.0640	S-19
$E3$	Insulate lead between layers, both sides	0.0406	S-4
$F3$	Change reel	0.0579	S-6
$G3$	Rewind wire on new reel	0.0050	S-7

Synthesis:

$D + E + F + I + J + K + L + M + 2N + M1 + 2\text{-}O1 + B2 + C2 + D2 + E2 + G2 + O2 = 0.0050 + 0.0269 + 0.0078 + 0.0042 + 0.0066 + 0.0057 + 0.0050 + 0.0066 + 0.0058 + 0.0040 + 0.0034 + 0.0026 + 0.0089 + 0.0230 + 0.0061 + 0.0180 + 0.0035 = 0.1431$ = constant for straight-up coils.

$D + E + F + 2I + J + K + L + 2M + 6N + 4\text{-}O1 + T1 + U1 + V1 + W1 + X1 + B2 + C2 + 4D2 + E2 + G2 + O2 + M1 = 0.0050 + 0.0269 + 0.0078 + 0.0084 + 0.0066 + 0.0057 + 0.0050 + 0.0132 + 0.0174 + 0.0080 + 0.0209 + 0.0287 + 0.0034 + 0.0080 + 0.0105 + 0.0034 + 0.0026 + 0.0356 + 0.0230 + 0.0061 + 0.0180 + 0.0035 = 0.2677$ = constant for two-half coils.

Curve 1 = A and $A + G$.
Curve 2 = Q.
Curve 3 = P.
Curve 4 = $H + P1 + Q1$.
Curve 5 = $B + C + S1 + R1 + Y1 + Z1 + A2$ for two-half coils.
$B + C + S1 + Y1 + Z1 + A2$ for straight-up coils.
Curve 6 = S = winding time.

$T + (V + W)\,4 = 0.0051 + (0.0013 + 0.0012)\,4 = 0.0051 + 0.0100 = 0.0151$ = time to place crossover patch and cut and place four pieces of 0.007 fuller board at corners.

$I2 + J2 = 0.0065 + 0.0078 = 0.0157$ = time to place one long cambric tie for two-half coils.

$O = 0.0008$ = time to tape 1 inch of wire.

$Y = 0.0025$ = time to place one plain lug.

$Z + A1 + B1 = 0.0028 + 0.0076 + 0.0013 = 0.0117$ = time to place one drawn lug.

$R2 = 0.0057$ = time to place one clamp.

$C1 + 2D1 + 2X2 + E1 + R1 + G1 + H1 + I1 + J1 + K1 + L1 = 0.0064 + 0.0040 + 0.0082 + 0.0130 + 0.0034 + 0.0136 + 0.0061 + 0.0030 + 0.0117 + 0.0061 + 0.0043 = 0.0798$, say, 0.0800 = time to make one short-circuit complete on two wires.

$K2 + P2 = 0.0638$ for trucking coils over 75 pounds to inspector's bench.

$2S2 + 4T2 + 2U2 + 2V2 = 0.0120 + 0.0208 + 0.0220 + 0.0204 = 0.0752$ = the time to place ventilation blocks on both ends of coil.

$Y2 + C3 = 0.0055 + 0.0331 = 0.0386$ = the time to insulate short-circuit and is used on straight-up coils when the finish lead is made from strap copper and the last two or three turns are short circuited.

$Z2 + A3 + B3 = 0.0774 + 0.0153 + 0.0123 = 0.1050$ = the time to place one plain strap-copper lead.

$Z2 + A3 + B3 + D3 + E3 = 0.0774 + 0.0153 + 0.0123 + 0.0640 + 0.0406 = 0.2096$ = the time to place one special strap-copper lead, *i.e.*, one that is brought across the coil between the first and second layer.

$F3 + G3 + T1 + U1 + V1 + W1 + X1 + M = 0.0579 + 0.0050 + 0.0209 + 0.0287 + 0.0034 + 0.0080 + 0.0105 + 0.0066 = 0.1410$, say, 0.1400 = time to change reel and make weld complete. Allow once for each 100 pounds of wire used.

Curve 6. Winding Time per Turn.—It was found that the winding time per turn was dependent mainly on two conditions; namely, the perimeter of the center block of the mold on which the coil is wound and the height of the wire used. In order to obtain consistent time, these two factors must be considered. This then gives three variables, namely, the perimeter of the center block, the height of the wire, and the time required.

In order to express the relation among the three variables, it was found convenient to use two interdependent curves. A number of studies were selected on coils where the height of the wire was nearly constant, thereby eliminating this factor temporarily. The time per turn for winding was plotted against the perimeter of the center block. The ordinate or time scale was then changed. The point at which the time is a minimum was taken as one and the point where this time doubles as two and so on. This curve then gives time factors instead of time.

After having determined this variable factor, all of the winding times secured were divided by it, thus in effect eliminating all of the influence of the perimeter or bringing them all to the basis of a constant center block perimeter. The remaining variation in the times per turn was then due to the height of the wire being wound. Another curve was then plotted using the time as ordinates and the wire height as abscissas which gave the relation of time to the height of the wire unaffected by perimeter.

To find the true time per turn for any coil, the height of the wire is found from the specifications and the time per turn for the given height is read from the curve. Then the perimeter of the center block is determined, and the factor is read from the factor curve for the given perimeter. The time read from the base curve is then multiplied by the factor read from the factor curve, and the result is the true time to wind one turn.

Inspection:

See inspection sheet from inspection department.

Payment:

Standard-time job basis.

Approved:

Time-study Supervisor	Time-study Department

SPECIAL INSTRUCTIONS

Let A = area of part to be cleaned.
B = perimeter of center block in inches.
C = height of coil in inches.
Then $A = B(C + \frac{1}{4})$.

Curve reading gives value for both sides on straight-up coils and both sides and collar on two-half coils.

When using curves 2 and 3 for two-half coils, consider each half as a separate coil. The winding space for the first half will be the total wire space minus the width of the collar. The winding space for the second half will be the same as the width of the collar.

On straight-up coils, the number of inches taped $= 2B$. On two-half coils, the number of inches taped $= 6B + 4\pi C$.

Plain lugs are lugs that are placed and the end wound over, and drawn lugs are lugs that are drawn into place with loop strings. In determining the number of lugs for a two-half coil, consider each half as a separate coil. If N = the number of layers in build, the number of lugs required may be determined as follows:

	When N is an Even Number		When N is an Odd Number	
Long Center Block Dimension	Plain Lugs	Drawn Lugs	Plain Lugs	Drawn Lugs
Up to 8 inches............	$\frac{3N}{2} + 4$	N	$\frac{3(N-1)}{2} + 4$	$N + 1$
Over 8 inches..............	$3N + 8$	$2N$	$3(N - 1) + 8$	$2(N + 1)$

When there is no build, $N = 1$.

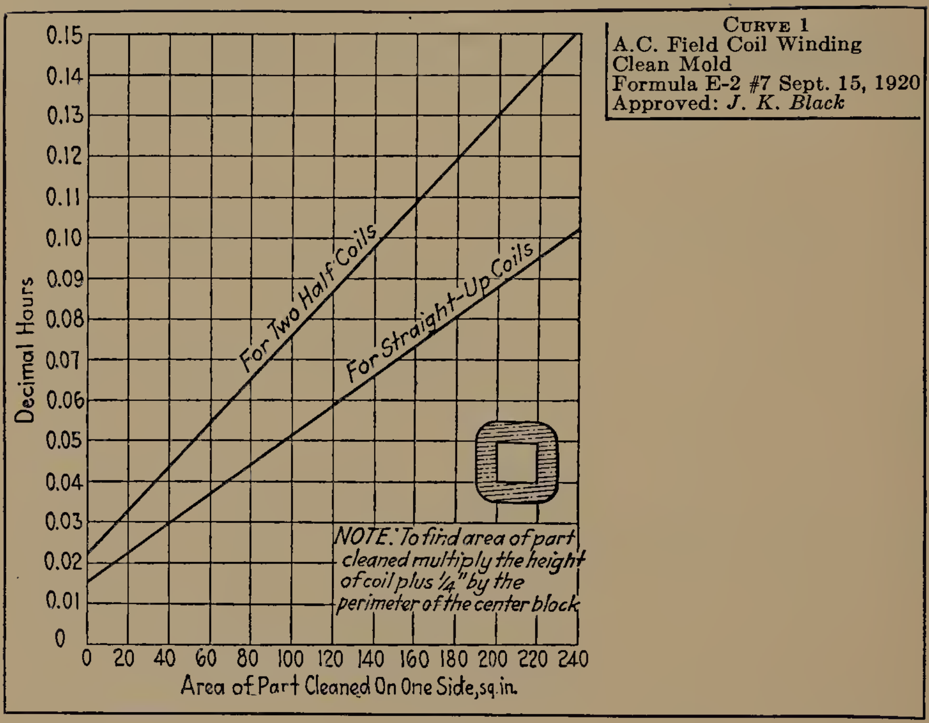
To use curve 6 for flat wire, calculate the size of square wire having an equal cross-section area to that of the flat wire, which would be Width × Thickness. Then for the abscissa of the curve, instead of the actual height, use this calculated height as determined.

The number of cambric ties used to tie two-half coils together is two for coils having long center-block dimension up to 8 inches and four for coils having long center-block dimension over 8 inches.

On all two-half coils having wire larger than 0.204-inch square flat wire with thickness larger than 0.204 inch and wire on edge with the height larger

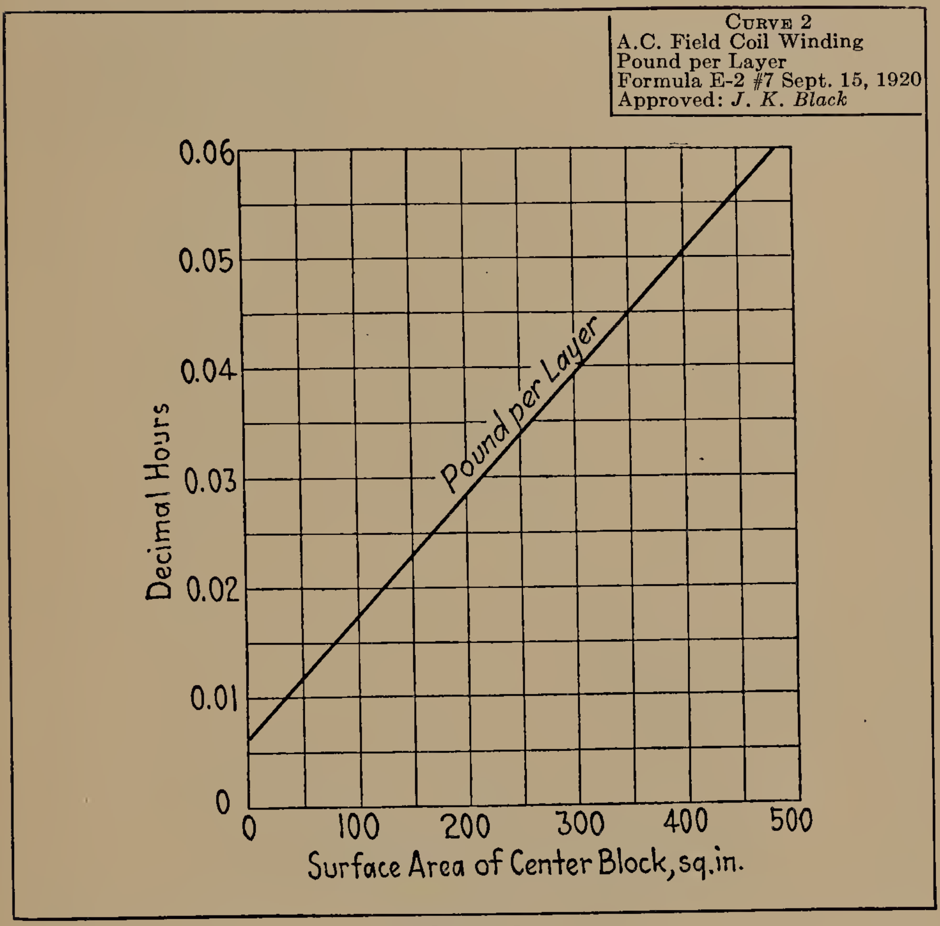
than 0.204 inch, allow one extra clamp. On all open coils wound straight up, allow two extra clamps. On all cross and special coils wound straight up, allow one extra clamp.

On straight-up coils when the finish lead is made from strap copper, the short-circuit is insulated with non-elastic tape for extra protection and mechanical purposes. This is referred to as insulating short-circuit in formula. Coils wound in two halves do not have strap-copper leads. When a strap-copper lead is put on and brought out at the same side, it is called a plain lead. When a strap-copper lead is placed on one side and brought across the coil between layers, it is called a special lead.

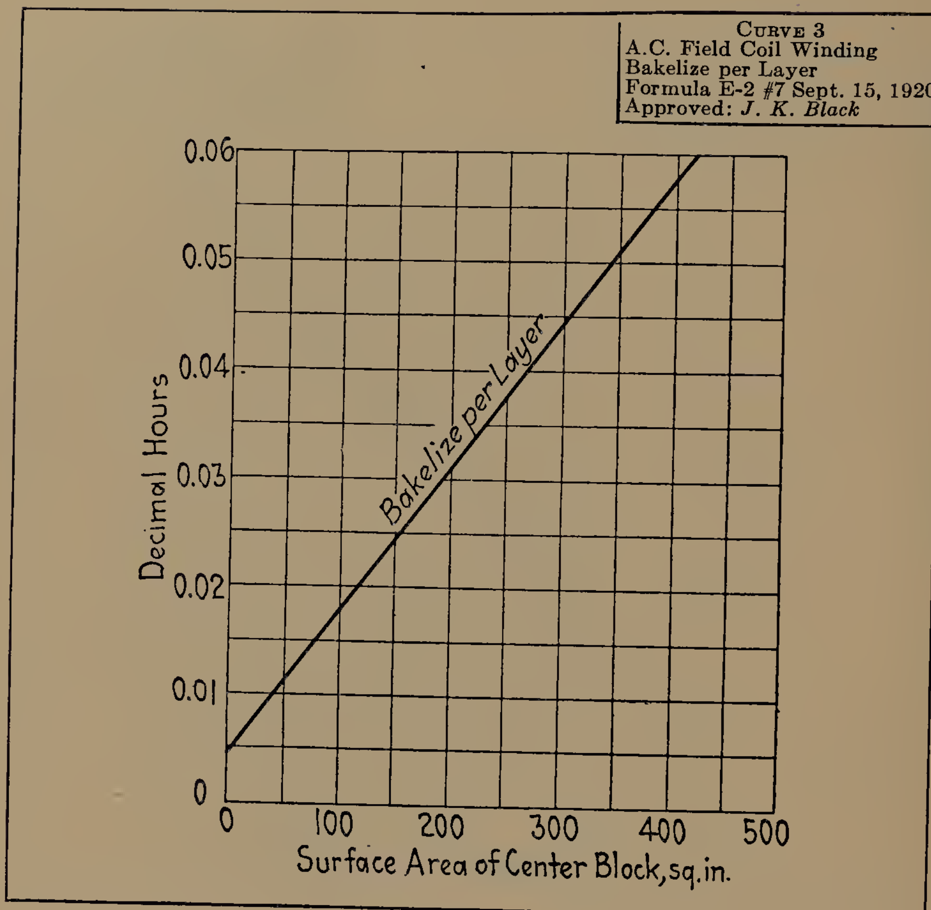


CURVE 1
A.C. Field Coil Winding
Clean Mold
Formula E-2 #7 Sept. 15, 1920
Approved: *J. K. Black*
Decimal Hours
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
For Two Half Coils
For Straight-Up Coils
NOTE: To find area of part cleaned multiply the height of coil plus 1/4" by the perimeter of the center block
0 20 40 60 80 100 120 140 160 180 200 220 240
Area of Part Cleaned On One Side, sq. in.

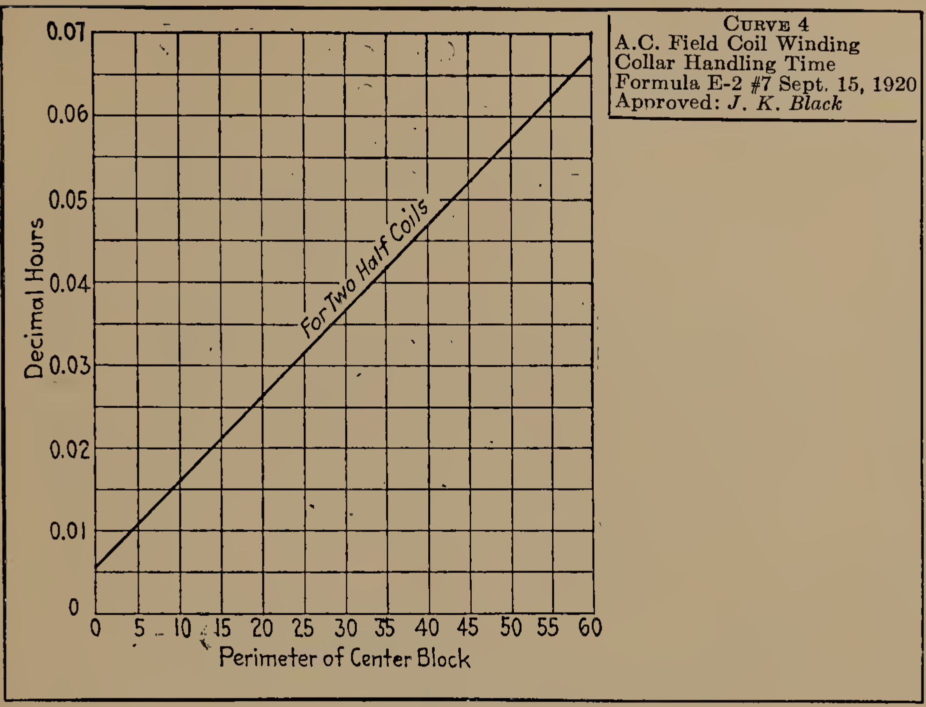
CURVE 1.


CURVE 2
A.C. Field Coil Winding
Pound per Layer
Formula E-2 #7 Sept. 15, 1920
Approved: J. K. Black
Decimal Hours
0.06
0.05
0.04
0.03
0.02
0.01
0
Pound per Layer
0
100
200
300
400
500
Surface Area of Center Block, sq. in.

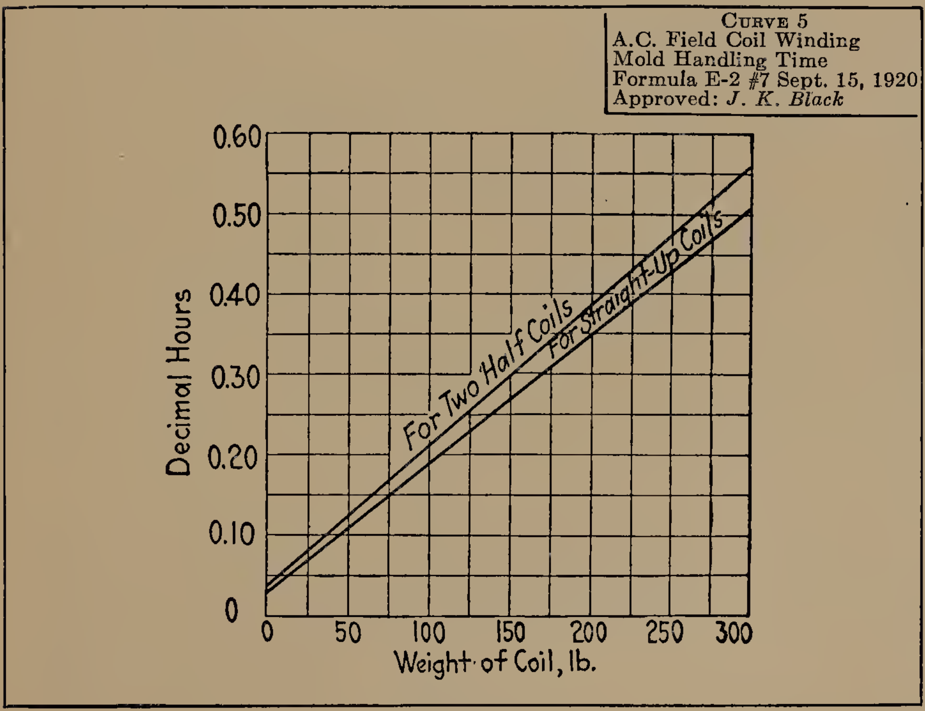
CURVE 2.


CURVE 3
A.C. Field Coil Winding
Bakelize per Layer
Formula E-2 #7 Sept. 15, 1920
Approved: *J. K. Black*
Decimal Hours
0
0.01
0.02
0.03
0.04
0.05
0.06
Bakelize per Layer
0
100
200
300
400
500
Surface Area of Center Block, sq. in.

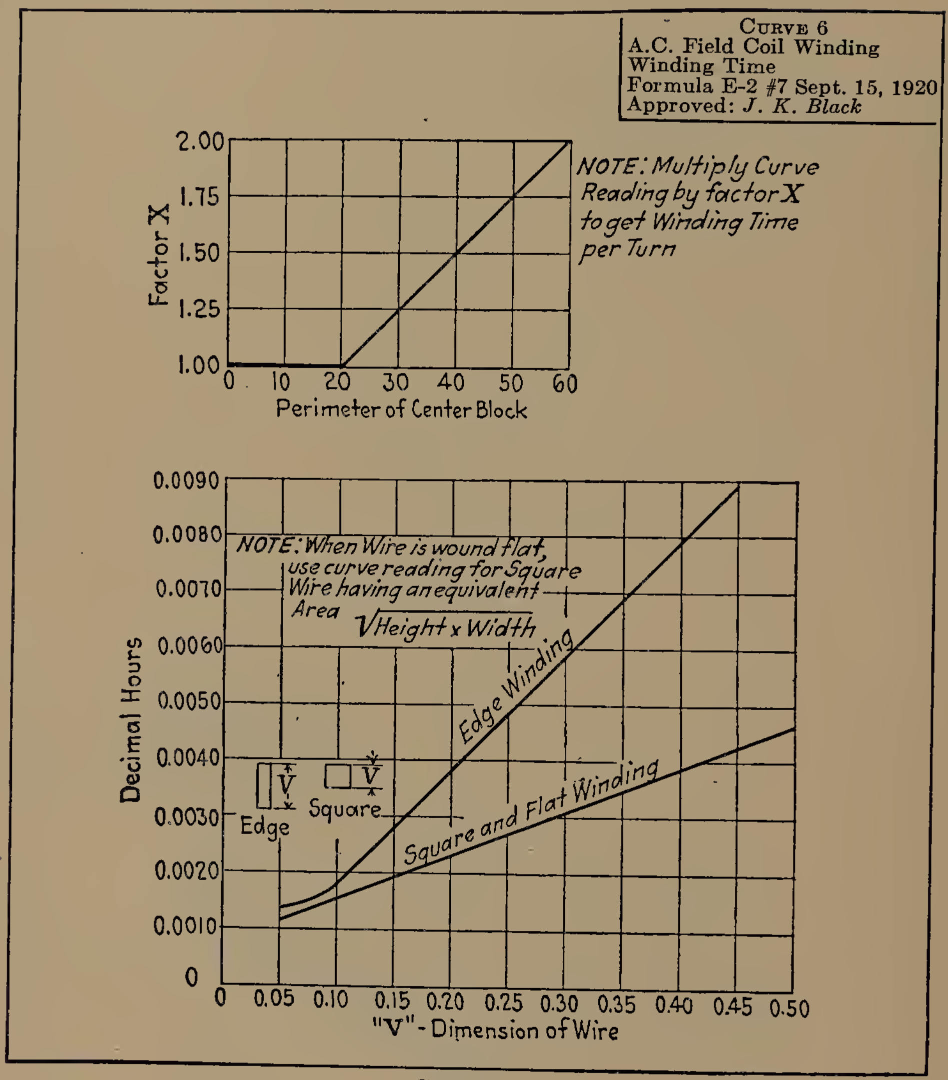
CURVE 3.



CURVE 4.



CURVE 5.


CURVE 6
A.C. Field Coil Winding
Winding Time
Formula E-2 #7 Sept. 15, 1920
Approved: J. K. Black
2.00
1.75
1.50
1.25
1.00
Factor X
0
10
20
30
40
50
60
Perimeter of Center Block
NOTE: Multiply Curve Reading by factor X to get Winding Time per Turn
0.0090
0.0080
0.0070
0.0060
0.0050
0.0040
0.0030
0.0020
0.0010
0
Decimal Hours
NOTE: When Wire is wound flat, use curve reading for Square Wire having an equivalent Area $\sqrt{Height \times Width}$
Edge Winding
Square and Flat Winding
V
Edge
V
Square
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
"V" - Dimension of Wire

CURVE 6.

CHAPTER XXXII

FORMULA FOR METAL RATIO

The functions of the time-study department are not limited to the establishing of time allowances, and the data which are collected and compiled by them are not always for the purpose of establishing time values. The formula example given in this chapter shows how a formula was compiled by the time-study department for another purpose.

In foundries where the nature of the work is not standard and the number of different patterns cast is large, one of the biggest problems is to distribute the cost of melting the excess metal such as is used for sprues, gates, and risers. The most accurate way would be to weigh the casting as poured including sprues, gates, and risers. Obviously this would be an expensive process where the number of different jobs made each day is large and almost of a non-repetitive nature. The usual way of determining the ratio of pounds of metal melted to pounds shipped is to classify all of the castings into groups according to weight, and then by weighing a number of jobs as poured and dividing the rough weight by the finished weight to determine for each group an average relation between the weight of the metal required to pour a casting and the weight of the casting as shipped. This relation is known as the metal ratio. The trouble with this plan is that the ratio determined is an average for a group varying in size and characteristics. Some castings may require excessive gating, some nothing but the sprue, and some one or more risers. The ratio, therefore, will be high for some and low for others. Those having too high a ratio will be overpriced, and those having too low a ratio will be underpriced. It is readily seen that when the output favored the castings with the low ratio, the foundry would produce castings at a loss and *vice versa*. This makes it necessary to make a periodic adjustment of metal ratios, whereas in reality there is no reason why the metal ratio for the same casting should change.

The example here given of the formula to determine metal ratios will explain how the above difficulties were overcome and

how inaccuracies were corrected in a brass foundry. The number of different alloys used made the problem somewhat difficult, but after sufficient study was made, it was found possible to resolve the formula into the comparatively simple form given. In actual application, when over 800,000 pounds of miscellaneous castings were checked, this formula gave a value only 2,500 pounds different from the actual or a difference of about three-tenths of 1 per cent.

Formula O-4 No. 15.
Aug. 1, 1925.

Part:

All alloy castings.

Metal Ratio:

See Master Chart.

Application:

This formula applies to the computation of all metal ratios for all castings made in section *O*-4 with the present equipment under the methods now used.

Analysis:

By "metal ratio" is meant the ratio of the number of pounds of metal charged into the furnaces to the number of pounds shipped.

A certain amount of metal is lost during melting by oxidation. This amount has been determined by engineering tests in terms of per cent of metal charged. Between the furnaces and the mold, and during pouring, a certain amount of metal is spilled. The proportion of the amount spilled to the amount shipped was determined by actually collecting and weighing the amount spilled during a period of a month. Spillage is greatest with white metal and smallest with copper. There is usually a small amount of metal left in each ladle after pouring, which is poured into chills and later remelted. The amount of this metal was determined by weighing up a representative day's chilled ingots.

A certain amount of metal over and above the metal in the finished casting must be poured into the mold to fill all gates, sprues, and risers. Gates provide passageway for the metal into the part of the mold which forms the casting from the sprue hole through which metal is poured into the mold. The metal in the sprue hole feeds down into the casting during cooling and tends to refill space left because of shrinkage. If the metal in the sprue hole is not sufficient, risers are added.

The difference between the weight of the rough casting as it is shaken out from the mold and the shipping weight of the finished casting is called the excess weight. For a given alloy, the excess weight varies as the shipping weight of the finished casting and also as the area of the casting. For a casting of a given weight, if the area is large, the excess weight is large because a large amount of gating is required to run the metal to all parts of the casting. As the area decreases, the finished weight remaining the

same, the amount of gating needed and hence excess weight decreases. The excess weight is a minimum where only the sprue is required to run the metal into the casting. As the area decreases still further beyond this point, the casting becomes chunky. Risers are needed to care for shrinkage and hence the excess weight increases again.

The ratio between shipping weight and area is what determines the effect of area on excess weight for any casting.

In order to express the relation among the three variables, excess weight, shipping weight, and the ratio of shipping weight to area, it is convenient to use two interdependent curves. For castings of a constant weight and given alloy, excess weight is plotted against the ratio of shipping weight to area. Since the casting weight is held constant, this curve shows the effect of area only on excess weight. This curve (see upper curve, Plate 2) is somewhat U-shaped. Excess weight is large where the weight is small in proportion to the area and decreases as this proportion increases. Finally the area becomes so small that the casting becomes chunky and requires risers and hence has greater excess weight.

This U-shaped curve is to be used with a curve from which the effect of area has been eliminated in order to obtain true excess weights for any condition. The ordinate scale for the U-shaped curve is changed. The point at which the excess weight is a minimum is taken as one, the point where the minimum excess weight doubles as two, and so on. Then dividing the excess weight of any casting by the factor read on the new scale for the proper ratio of shipping weight to area gives an excess weight from which the effect of area has been removed. Such points may be plotted against shipping weight, and the resulting curve gives the relation between shipping weight and excess weight, unaffected by area.

To find the true excess weight for any casting, the excess weight read from the lower curve in Plate 2 is multiplied by the factor X read from the upper curve. The result is the true excess weight with both shipping weight and area considered.

The same factor X curve may be used for all alloys. The curves found by dividing excess weight by factor X and plotting the result against shipping weight will be found to differ with the alloy. For instance, copper has a high shrinkage per inch and hence requires more excess metal to feed the casting during cooling than does alloy 4 with a lower shrinkage per inch.

It was found that the curves for white metal, copper and alloy 6 differed from one another and from the curves for brass. It was also found that the curves for alloys 4, 5, 7, 8, 9, 26, and 31 coincide for castings weighing 18 pounds or over but for smaller weights the curve for alloys 4 and 31 is somewhat lower than that for the other alloys.

Data:

A number of representative castings for each alloy were weighed and measured before and after sawing and grinding. This gave the necessary data of rough weight, finished weight, and area.

The amount of metal lost by oxidation was taken from cost department figures which were determined from actual tests. The amount poured back into chills was determined by actual weighing as was the amount of dross.

Synthesis:

Let C = constant covering oxidation loss, amount poured back into chills, and dross.

Fx = factor X (from upper curve, Plate 2).

R = rough weight of casting when taken from mold.

S = shipping weight.

Wc = weight charged into furnace.

X = true excess weight.

Xc = excess weight (read from lower curve, Plate 2) with the effect of area eliminated.

$$\text{Metal ratio} = \frac{Wc}{S} = \frac{RC}{S} = \frac{(X + S)}{S}C = \frac{(FxXc + S)}{S}C = \frac{FxXc\ C}{S} + C.$$

To determine C, the constant percentage covering oxidation loss, amount poured back into chills and dross,

let Po = per cent lost by oxidation of metal charged into furnace.

Pc = per cent poured back into chills of rough weight.

Pd = per cent dross figured from total dross divided by amount shipped.

Assume that average metal ratio = 2.36.

$\dfrac{100}{100 - Po}$ = per cent of rough weight + dross + amount poured back into chills lost by oxidation.

$\dfrac{100}{100 - \left(Pc + \dfrac{Pd}{2.36}\right)}$ = per cent of rough weight spilled and poured back into chills.

$$\text{Then } C = \left(\frac{100}{100 - Po}\right)\left(\frac{100}{100 - \left(Pc + \dfrac{Pd}{2.36}\right)}\right)$$

Example for alloy 4: Po = 5.3.

Pc = 10.6.

Pd = 2.32.

$$\text{Substituting: } C = \frac{100}{100 - 5.3}\left(\frac{100}{100 - \left(10.6 + \dfrac{2.32}{2.36}\right)}\right)$$

= 119.2 per cent, say 119 per cent.

For stock sticks poured in iron molds, the metal ratio is given by $S \times C$

For all other castings the formula $\dfrac{FxXcC}{S} + C$ is used.

Master Chart:

The master chart allows the computation of metal ratio for castings of all alloys within the limits of the curves. All curves are plotted on logarithmic cross-section paper to permit the use of the alignment chart principle.

To compute a metal ratio, the procedure is as follows: Lay a straight-edge across the area and shipping weight scales above the factor X curve so that it intersects these scales at the area and weight of the casting under consideration. Where the straight-edge intersects the upper edge of the factor X curve read the ratio of shipping weight to area. Read the corresponding factor X from the curve. On the proper curve to the right read the excess

weight for the given shipping weight. These curves have all been increased by the percentage C and hence give XcC of the metal-ratio equation direct. Connect by a straight-edge the factor X reading on the right-hand edge of the factor X curve with the excess weight reading on the left-hand edge of the other curve. Where the straight-edge intersects the vertical logarithmic scale, read the quantity $FxXcC$. Keeping this point on the vertical logarithmic scale, swing the straight-edge about this point until it intersects the right-hand edge of the factor X curve at the point corresponding to the shipping weight of the casting. Read on the left-hand edge of the other curve the result of $\frac{FxXcC}{S}$. To this add the constant given in Table I. The result is the solution of the equation $\frac{FxXcC}{S} + C$, or the metal ratio.

Charts I to V.—Charts I to V enable the finding of metal ratios direct without the necessity of going through the computations involved in the use of the Master Chart.

The charts were constructed as follows: For each group of alloys, metal ratios for a number of different weights and area were worked out and tabulated as shown in the table for alloy 4, Plate 3. From this table lines of constant area were plotted for metal ratio against shipping weight as shown partially in Plate 4. From these curves, lines of constant metal ratio were plotted as shown on Charts I to V.

Approved:

Time-study Supervisor	Time-study Department

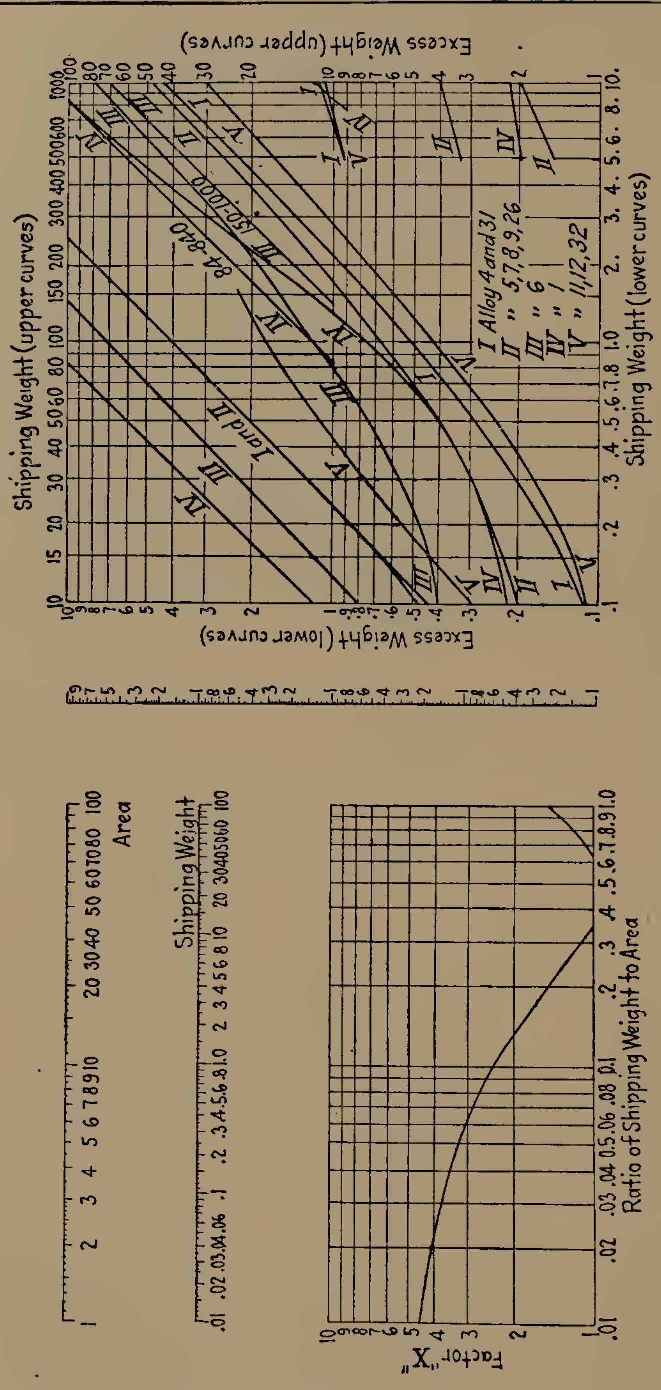


TABLE I

Alloy	C
4 & 31	1.19
5, 7, 8, 9, 26	1.16
6	1.26
1	1.13
11, 12, 32	1.33

PLATE 1.— Master chart.

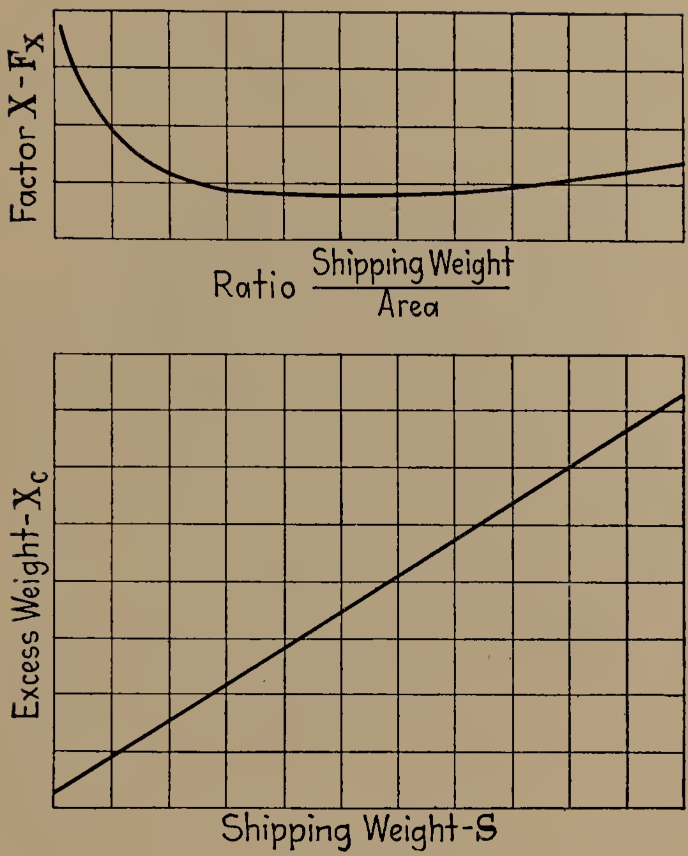

Factor X - F_X
Ratio $\frac{\text{Shipping Weight}}{\text{Area}}$
Excess Weight - X_c
Shipping Weight - S

PLATE 2.

AREA

Shipping Weight (Metal Ratio)	1	3	5	10	15	20	25	30	40	50	70	100	125	150	200	250
0.125	3.30	4.59	5.07	5.59												
0.25	2.09	3.07	3.51	3.99	4.09	4.35	4.52					Alloy 4				
0.5	1.83	2.17	2.58	3.09	3.30	3.45	3.55	3.63	3.76	3.88						
0.75	1.79	1.93	2.17	2.67	2.92	3.07	3.18	3.26	3.37	3.45	3.60					
1.0	1.94	1.71	1.96	2.41	2.68	2.85	2.96	3.09	3.16	3.25	3.38	3.54				
1.5		1.71	1.72	2.07	2.34	2.52	2.65	2.76	2.87	2.96	3.10	3.23	3.27	3.45		
2.0		1.68	1.65	1.90	2.12	2.32	2.54	2.64	2.72	2.81	2.91	3.09	3.17	3.22	3.36	
2.5		1.76	1.65	1.77	1.96	2.15	2.29	2.40	2.69	2.69	2.56	2.97	3.03	3.11	3.21	3.31
3.0		1.88	1.65	1.72	1.89	2.04	2.18	2.31	2.49	2.61	2.77	2.89	2.98	3.03	3.13	3.23
3.5			1.68	1.65	1.80	1.93	2.07	2.19	2.36	2.49	2.67	2.83	2.92	2.96	3.03	3.14
4.0			1.72	1.64	1.73	1.86	1.98	2.09	2.27	2.39	2.58	2.76	2.86	2.91	3.01	3.10
4.5			1.80	1.64	1.69	1.80	1.90	2.02	2.20	2.33	2.53	2.70	2.80	2.87	2.97	3.04
5.0			1.87	1.64	1.64	1.76	1.85	1.96	2.13	2.27	2.47	2.65	2.75	2.83	2.94	3.01
6.0				1.64	1.64	1.68	1.77	1.85	2.00	2.15	2.36	2.56	2.66	2.74	2.86	2.93
7.0				1.67	1.64	1.64	1.71	1.79	1.93	2.05	2.26	2.47	2.56	2.66	2.79	2.89
8.0				1.72	1.64	1.64	1.66	1.72	1.86	1.97	2.17	2.35	2.52	2.61	2.75	2.83
9.0				1.79	1.64	1.63	1.63	1.67	1.79	1.89	2.08	2.32	2.45	2.54	2.67	2.76
10.0				1.85	1.65	1.63	1.63	1.65	1.75	1.85	2.02	2.25	2.38	2.47	2.62	2.72
12.0					1.70	1.62	1.63	1.62	1.68	1.77	1.91	2.11	2.23	2.36	2.52	2.62
14.0					1.79	1.66	1.62	1.62	1.62	1.69	1.83	2.02	2.14	2.25	2.43	2.52
16.0						1.70	1.64	1.61	1.62	1.64	1.77	1.93	2.06	2.18	2.35	2.46
18.0						1.76	1.66	1.62	1.62	1.62	1.73	1.88	2.00	2.17	2.27	2.39
20.0						1.83	1.69	1.64	1.62	1.62	1.68	1.83	1.93	2.03	2.21	2.34
25.0							1.82	1.71	1.62	1.61	1.61	1.72	1.82	1.90	2.06	2.20
30.0								1.81	1.66	1.61	1.61	1.66	1.73	1.82	1.96	2.08
35.0									1.72	1.64	1.61	1.60	1.67	1.74	1.87	1.99
38.0									1.78	1.66	1.61	1.60	1.65	1.71	1.83	1.94

PLATE 3.—Metal ratio table computed from Master Chart.

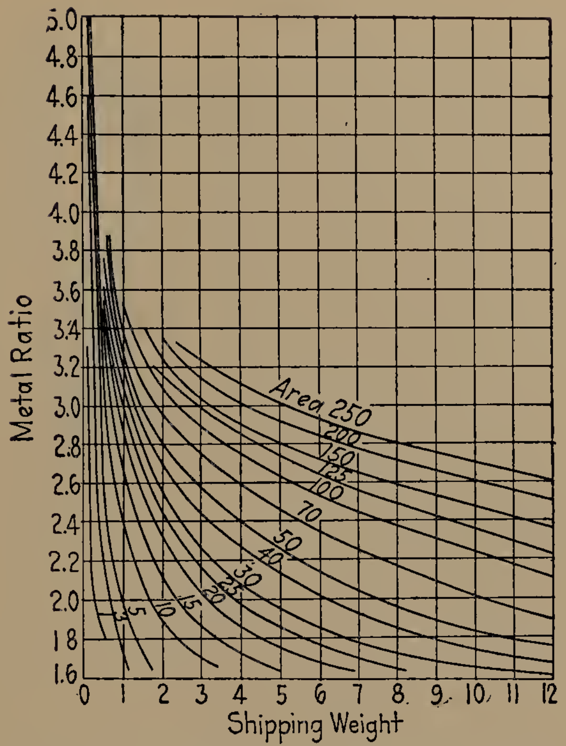


PLATE 4.—Curves used for constructing Chart I.

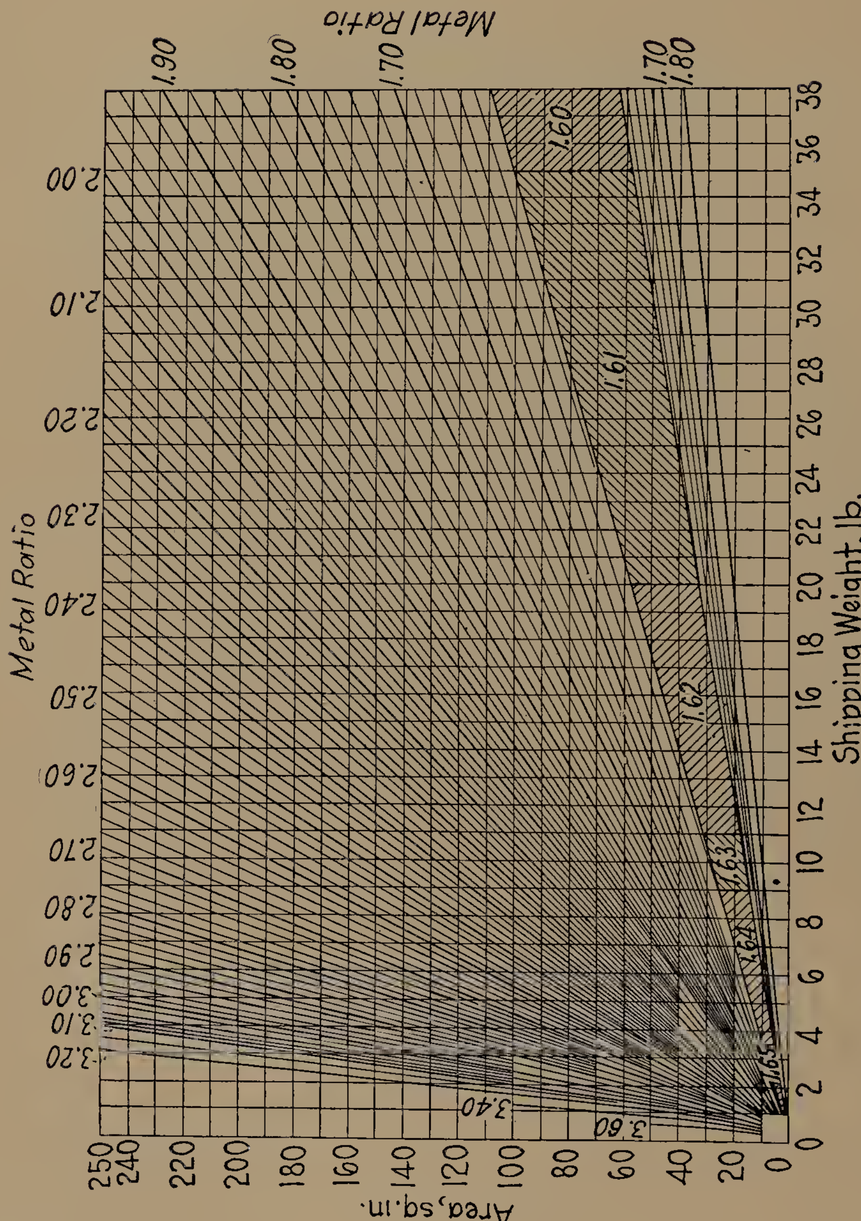


CHART I.—For alloys 4 and 31.

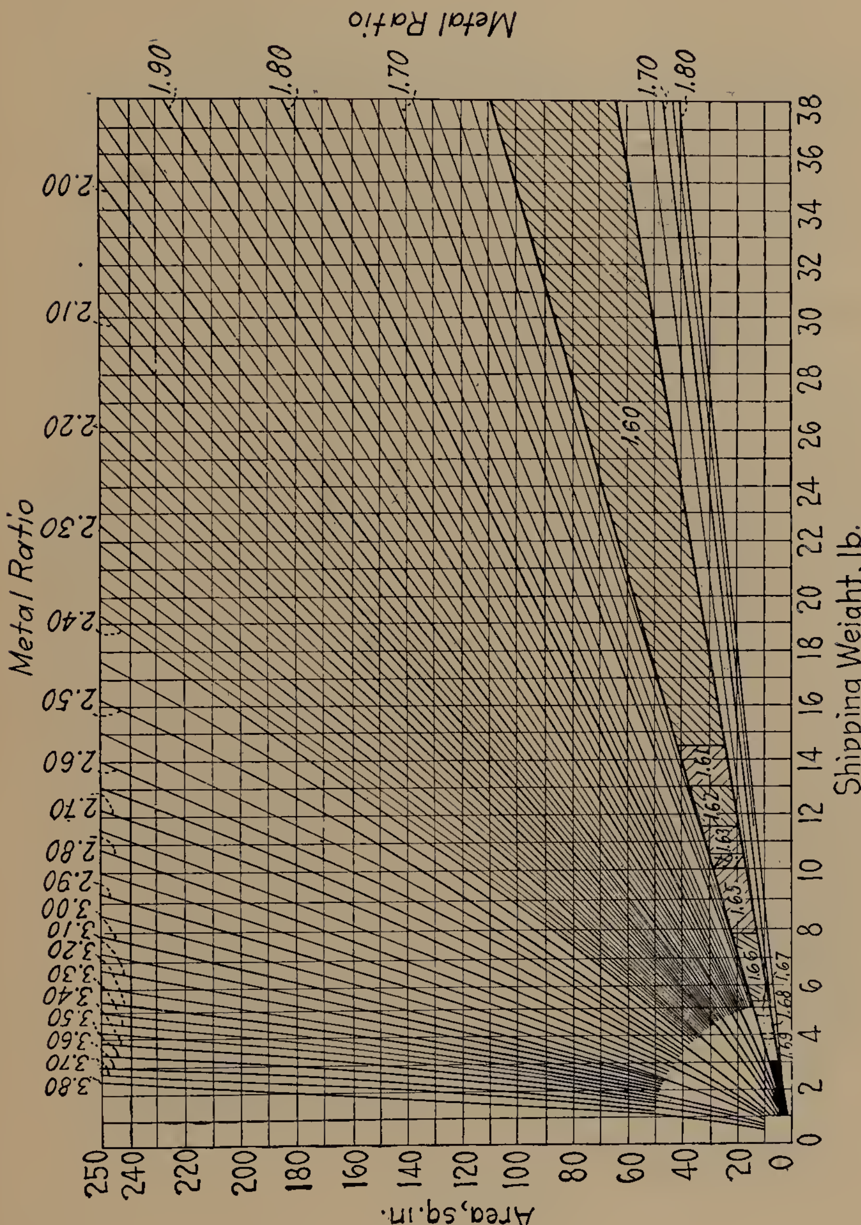


CHART II.—For alloys 5, 7, 8, 9 and 26.

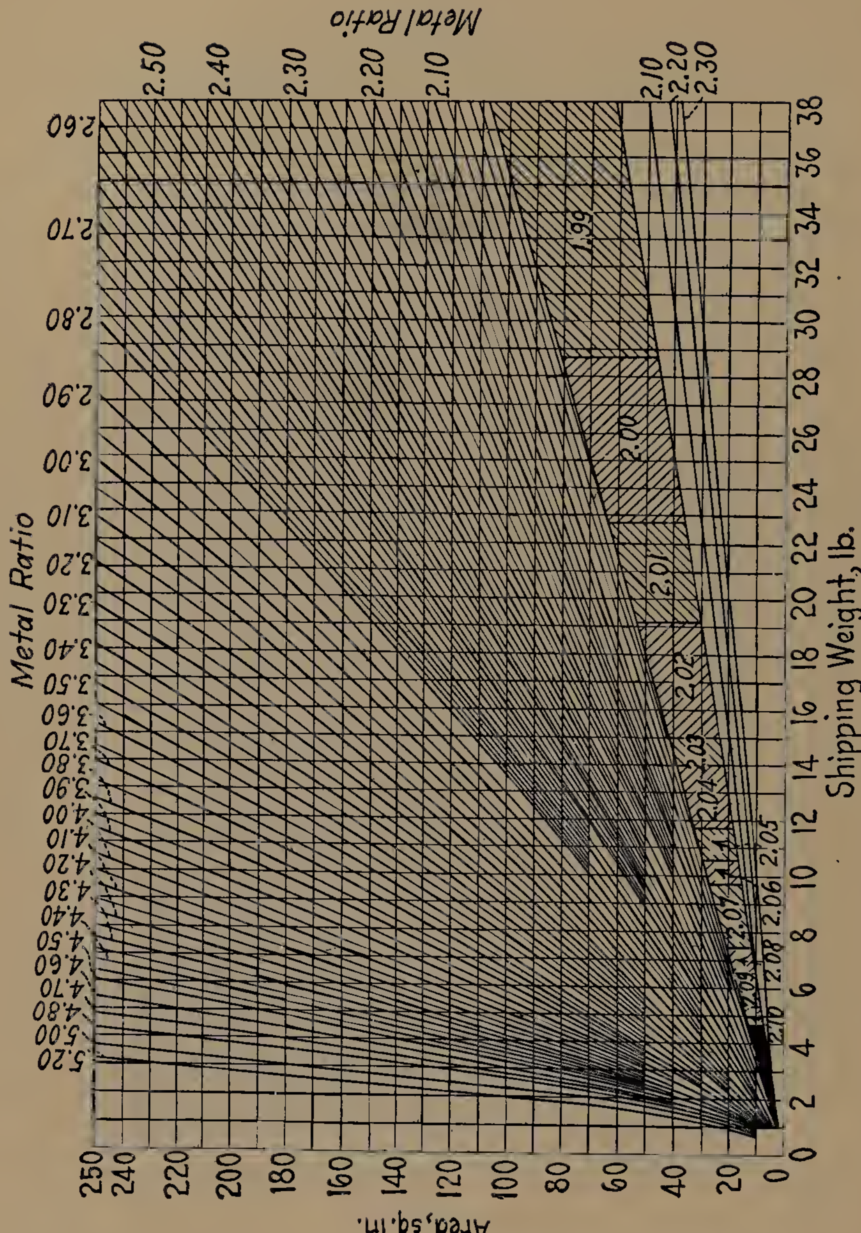


CHART III.—For alloy 6.

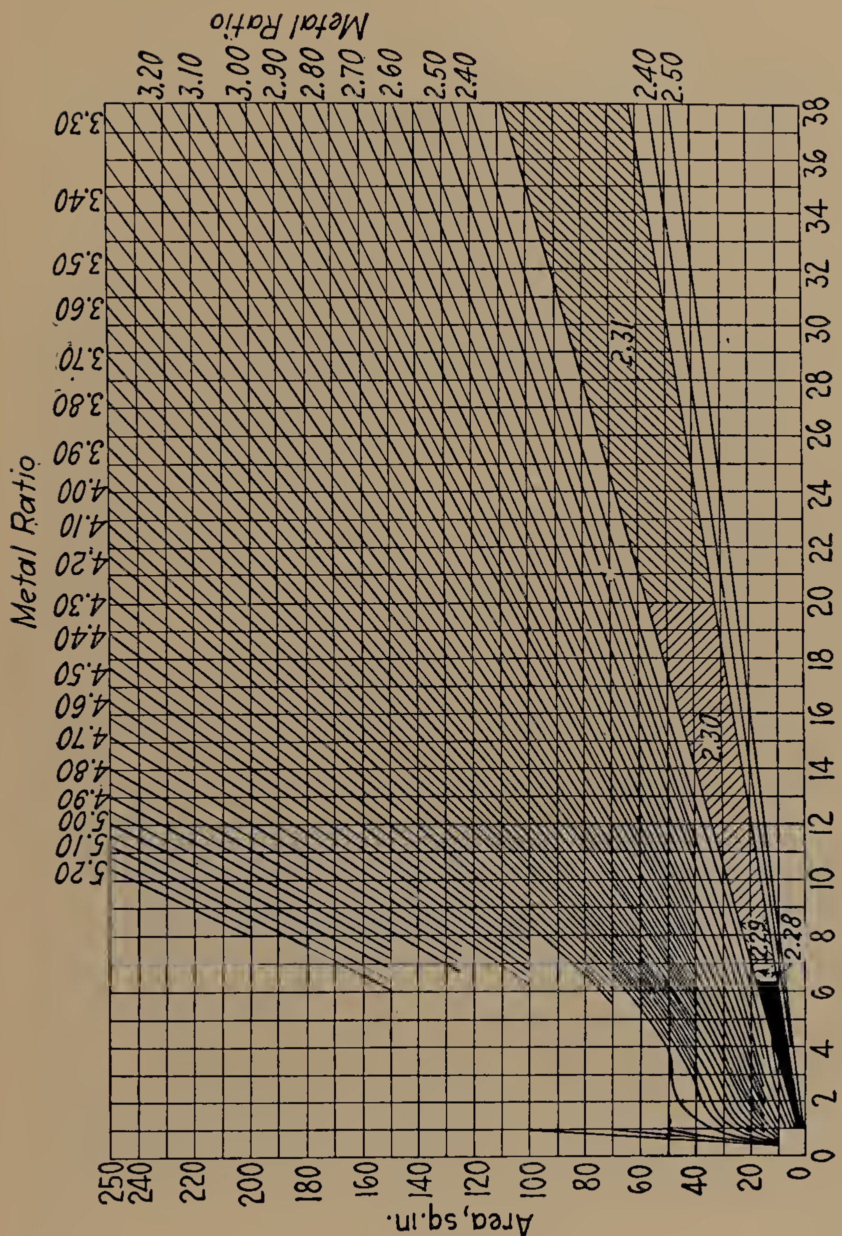


CHART IV.—For alloy 1.

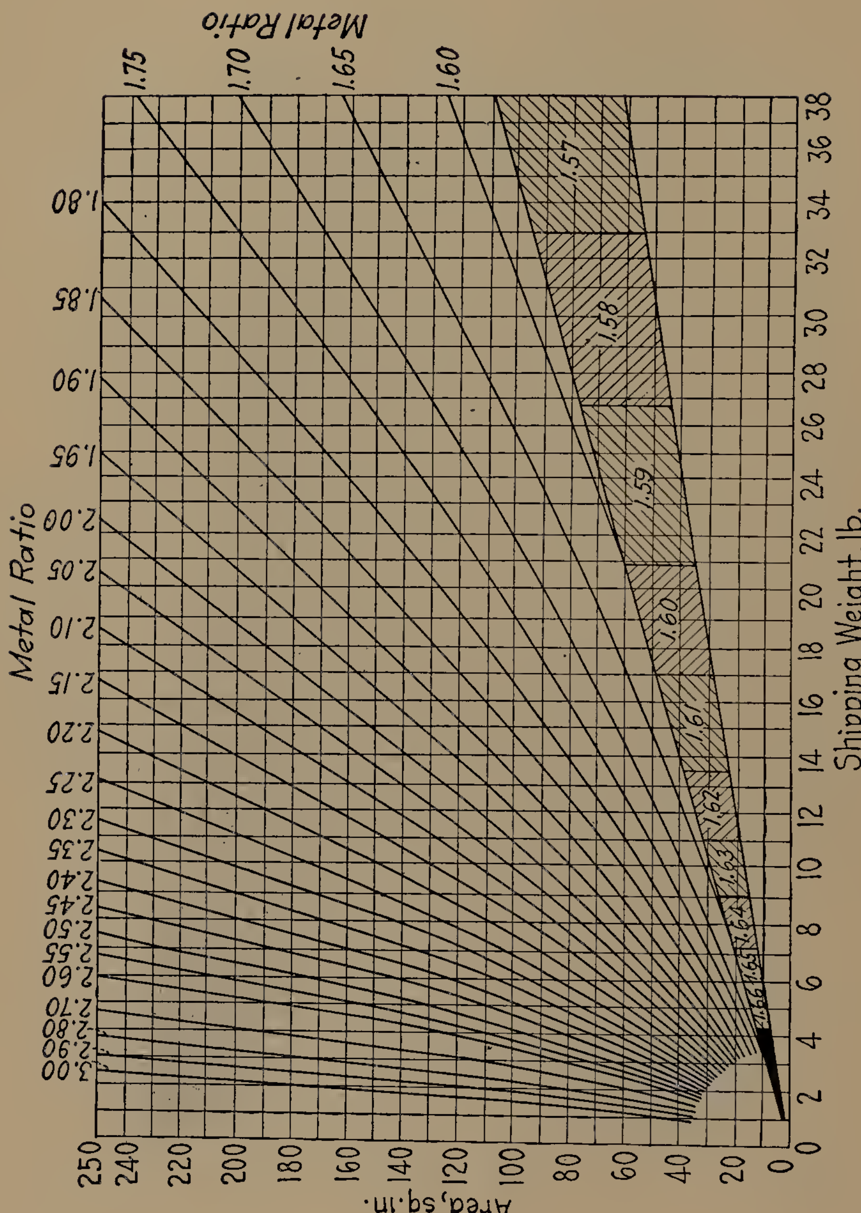


CHART V.—For alloys 11, 12 and 32.

CHAPTER XXXIII

FORMULA FOR CHIP CASTINGS

Formula Power General No. 1 is for the operation "chip castings." After these castings are delivered to the machine and assembly shop from the foundry, they are machined, and quite often after machining, irregularities appear which can be corrected only by chipping with an air hammer. These castings are usually covered with scale or rust, which is also best removed by chipping.

This operation was always considered a straight day-work operation because of the difficulty in estimating the time required to perform it. To add to the difficulties, the amount of chipping necessary was not constant on the same casting each time it came through the shop. Some method had to be developed which would take care of all of these difficulties satisfactorily. How this was accomplished is explained in the formula. It was considered impossible by several men not familiar with formula possibilities to compile a satisfactory formula for this work. After the data were collected and the formula finished, however, these same men were ready to admit their error and are now completely convinced on the formula method of establishing time values. This formula has made it possible to put the chipping work on an incentive basis. It has given greatly increased production, lower costs, higher earnings, and less labor turnover. While this formula is fairly simple in its finished state, the keen judgment and analytical ability required in its making is apparent. Work of this kind where the human element plays such a large part in its performance is usually the most difficult to formulate.

Formula, Power General No. 1.
Jan. 1, 1926.

Part:
Castings.

Operation:
Chip.

Work Station:

Floor.

Allowed Time:

$$0.3455 + SA + 0.4600G + 0.1955X + 0.0029Y + 0.0014Z + \left(\frac{T}{t}\right)\left(\frac{W}{w}\right)LF,^*$$

where A = see Table I.
F = see Table II.
G = number of grooved hub spiders chipped.
L = length of part being chipped off in inches.
S = number of square feet from which scale is chipped.
T = thickness of part being chipped off in inches.
t = see Table II.
W = width of part being chipped off in inches.
w = see Table II.
X = number of times casting is turned over by crane.
Y = number of inches of beveling to be done.
Z = number of inches of filing to be done.

Table I.—Chip Scale

Class	Decimal Hours per Square Foot
Simple	0.0760
Medium	0.1150
Complex	0.2300

Table II.—Remove Section by Chipping

	t	w	F
Chip steel casting, depth less than $\frac{3}{16}$ inch	0.0625	1.0	0.0115
Chip steel casting, depth $\frac{3}{16}$ inch or more	0.200	0.25	0.0115
Chip all cast-iron castings	0.0625	1.0	0.0072

Application:

This formula applies to all castings which require chipping in the power department as done with air hammer under present conditions.

Analysis:

Tools and equipment needed are: air hammer, air hose, chisels, one chisel about 2 feet long, one narrow chisel or gouge, several chisels $\frac{3}{4}$ to 1 inch wide, one heavy flat file, one heavy rounded file, one wire and one soft brush, rule, and goggles.

In Secs. A-11 and C-1 the operator gets card from clerk, then locates casting which is stored near machining sections, and gets crane which delivers casting to space allotted for chipping.

* Consider all fractions resulting from the division $\left(\frac{T}{t}\right)$ and $\left(\frac{W}{w}\right)$ as one. Example: $\frac{0.3}{0.2} = 1\frac{1}{2}$. Use 2.

In *B* aisle, castings are brought to chipping space directly from machines to some extent so that it is not always necessary for operator to get casting. Work is initiated on order of foreman directly to operators.

In *D* aisle, castings are usually chipped wherever they may be located after machining operations are completed.

Similar castings will vary considerably in degree of smoothness, uniformity, and in temper of metal, so that there will be a consequent wide variation in time required to perform the chipping operations on them. This necessitates the construction of a formula that will compensate for the diversity of conditions existent in similar castings as well as for various classes of castings.

This has been accomplished by basing the formula on a unit of cut so that a time value may be set that represents the time necessary for the actual amount of chipping to be done on each particular job. In order to counterbalance such castings as may be unusually hard in temper, 5 per cent has been added to selected value for a unit cut.

As a further means of equalizing variations in quantity and quality of material removed from castings, the performance should be checked and operator paid on the 2-week pay period basis. That is, all work will be averaged up for a period of 2 weeks, and payment will be based on this average instead of on a per job basis. This spreading of time over 2 weeks permits basing payment on average conditions and thus represents an equitable method of payment.

To allow for time spent in sharpening of chisels, 10 per cent is added to overall time on each job; 10 per cent being an average based on several studies covering a variety of conditions.

In handling time, certain values are constant for all jobs. An allowance is made for getting time card, getting casting, getting tools ready, and waiting for crane to remove casting.

These values are summed up as a constant for all jobs. This will apply to those jobs to which the operator may go in some other part of the section in which he works, for the allowance for crane time will compensate time necessary to gather tools and equipment and go to location of casting.

All castings will not receive an equal amount of crane handling, so that the variable $0.1955X$ will allow for each crane move necessary during the chipping operations. Some castings will be chipped in original position as left by crane; others will require one to three turns depending on type of casting and kind of chipping that is to be done on it. The time-study man can readily determine the application of this variable when setting the time value on the job.

Scale on castings will vary in amount both as to total area covered and brittleness or thickness of scale. Black brittle scale, in general, is the easiest to remove. In classifying castings for scale, the accessibility and expanse of area to be scaled are of primary consideration. Readily accessible parts which provide a broad surface are obviously more easily cleaned than parts difficult of access and those which are intricate in design presenting limited consecutive areas for scaling. Castings are, therefore, divided into simple, medium, and complex classes when considering chipping of scale. It would not be practical to attempt to classify it further on basis

of quality of scale, as that is not readily determined, and favorable conditions will equalize unfavorable conditions.

Some operations in chipping, such as hand handling small castings and cleaning castings with air are not common to all jobs, but they are common to all operators. To avoid complexity in the formula, 5 per cent has been added to the overall time on all jobs to take care of such operations as are peculiar to certain castings and are not otherwise expressed in the formula.

Where several small castings which may be transported by one crane move are on one time order, handling time will be allowed only once for the total number of castings on that order and not separately for each casting.

Scale Classification:

Simple: Smooth, accessible, broad surfaces, no narrow strips or corners to chip out. Example: frame.

Medium: Comparative smooth and fairly accessible parts to scale. Area to be chipped rather smooth and broad if rather difficult of access. Easy of access if design is somewhat intricate.

Complex: Narrow strips, pockets and parts difficult of access, or limited in area in proportion to intricacy of design.

Procedure:

Get time card, get casting with crane, place casting, chip risers, partings, rough spots, chip to fit, bevel edges, file edges, chip scale, chip out sand, turn casting by hand or wait for crane and turn casting, sharpen chisels, remove casting.

Table of Details

Symbol	Operation Description	Standard Time	Reference
A	Get time card	0.0810	Average *S*-5, *S*-1, *S*-2
B	Get casting	0.0918	Average *S*-1, *S*-1, *S*-18, *S*-5
C	Get ready	0.0560	*S*-11, *S*-2
D	Bevel holes, per inch	0.0025	*S*-5, *S*-1
E	File edges, per inch	0.0012	*S*-7, *S*-1
G	Clean casting with air	0.0472	*S*-11, *S*-2
M	Wait for crane	0.1218	*S*-2, *S*-2
N	Turn casting	0.0484	*S*-9, *S*-1
T	Wait for crane to remove casting	0.0631	*S*-3, *S*-1
W	Chip sand in groove hub of spiders	0.3525	*S*-6, *S*-2
X	Remove scale, per unit, simple	0.0666	Average *S*-3, *S*-4, *S*-9, *S*-4, *S*-6
Y	Remove scale, per unit, medium	0.1000	Average *S*-1, *S*-1, *S*-2, *S*-2
Z	Remove scale, per unit, complex	0.2000	Average *S*-9, *S*-3
*A*1	Blow out groove	0.0540	*S*-9, *S*-2
*M*1	Chip metal, per unit	0.0095	*S*-12, *S*-2
*N*1	Place casting with hand hoist	0.0177	*S*-16, *S*-3
*R*1	Move to opposite side of casting	0.0154	*S*-12, *S*-4
*S*1	Set casting on bench by hand	0.0170	*S*-2, *S*-5
*T*1	Turn casting over by hand	0.0075	*S*-2, *S*-5

TABLE OF DETAILS.—(*Continued*)

Symbol	Operation Description	Standard Time	Reference
*W*1	Clean hole	0.0285	*S*-6, *S*-5
*A*2	Tap eyebolt if loose	0.0208	*S*-1, *S*-5
*B*2	Set casting on floor by hand	0.0096	*S*-6, *S*-5
*C*2	Wrap paper around machine	0.0439	*S*-16, *S*-5
*E*2	Take paper off machine	0.0156	*S*-16, *S*-5
*H*2	Separate two halves of casting	0.0437	*S*-11, *S*-5

Synthesis:

$A + B + C + T = 0.0810 + 0.0918 + 0.0560 + 0.0631 = 0.2919$ say, $0.3000 =$ constant for H or handling time.

$M + N = 0.1218 + 0.0484 = 0.1702$, say, $0.1700 =$ constant for each turning over of casting by crane during chipping operations.

$W + A1 = 0.3525 + 0.0540 = 0.4065$, say, $0.4000 =$ constant for cleaning out groove in hub of spiders.

In heavy chipping, a gouge or narrow rounded chisel will be used, as the resistance from the steel will be less per volume of cut than with a flat chisel. From study *S*-12 and *S*-2, on a $\frac{3}{16}$-inch riser, it was determined that an average cut was 0.2 by 0.25 inch. Then by computation it was determined that a cut 0.2 by 0.25 by 1 inch required 0.0095 decimal hour. This volume 0.2 by 0.25 by 1 inch is now a constant measure of cut for any chipping $\frac{3}{16}$ inch or greater in depth. To allow for cases of unusual hardness, where the time 0.0095 decimal hour would be inadequate, 5 per cent is added, making 0.0100 decimal hour the constant of time for a unit cut on material $\frac{3}{16}$ inch or greater in depth.

The expression for this is $\frac{T}{t} \times \frac{W}{w} \times L0.0100$.

To interpret, $\frac{T}{0.2} \times \frac{W}{0.25} \times L0.0100$, that is, 0.2 inch = constant of depth, 0.25 inch = constant of width, 0.0100 = constant of time for a unit cut on material $\frac{3}{16}$ inch or greater in depth.

When the depth of cut is less than $\frac{3}{16}$ inch, that is, $\frac{1}{16}$ or $\frac{1}{8}$ inch, a different constant must be used.

By computation, it was determined that a cut $\frac{1}{16}$ by 1 by 1 inch requires 0.0100 decimal hour. Chipping twice as deep, or $\frac{1}{8}$ inch, will require time in direct proportion to the increase in resistance due to increased depth of cut. Since the resistance is in direct proportion to the depth of cut, the time required will be in the same relation.

Removing material greater in length and breadth will, obviously, require time in direct ratio to area of material removed. Then, since chipping off material greater in volume requires time in direct proportion to the volume removed, $\frac{1}{16}$ by 1 by 1 inch is established as a constant unit of cut, and 0.0100 decimal hour as a constant of time for all steel chipping $\frac{1}{16}$ or $\frac{1}{8}$ inch in depth.

The expression for this is $\frac{T}{t} \times \frac{W}{w} \times L0.0100$.

To interpret, $\frac{T}{0.0625} \times \frac{W}{1} \times L0.0100$, that is 0.0625 = constant of depth, 1 inch = constant of width, and 0.0100 = constant of time for a unit cut.

TWL = volume of material removed.

Basis for $\left(\frac{T}{t}\right)\left(\frac{W}{w}\right) L0.0060$ cast iron.

It was found for cast iron that 0.0057 decimal hour is required to make a cut 0.0625 by 1 by 1 inch. To take care of cases of unusual hardness, 5 per cent is added to selected value 0.0057, making it 0.0060 decimal hour, or a constant of time for a unit of cut 0.0625 by 1 by 1 inch.

Then using 0.0625 inch or depth of unit cut, and 1 inch or width of unit as constants, t will always = 0.0625 inch and w will always = 1 inch.

Since it requires 0.0060 decimal hour to remove a unit of measure expressed by 0.0625 by 1 by 1 inch, it is logical to assume that the time required to chip additional amounts will increase in proportion to the increase in volume. This is substantiated by studies listed on chart.

The expression for formula is $\frac{T}{t} \times \frac{W}{w} \times L0.0060$.

To interpret, $\frac{T}{0.0625} \times \frac{W}{1} \times L0.0060$, that is, 0.0625 inch = constant of depth, 1 inch = constant of width, and 0.0060 = constant of time for a unit cut. These constants are to be used on all depths of cast-iron chipping.

TWL = volume of material to be removed.

D = 0.0025 = constant for beveling around holes in cast-iron casting.

E = 0.0012 = constant for filing chipped edges on cast-iron casting.

The average time required to sharpen chisels on all studies is 10 per cent of the total time for each casting. Therefore, 10 per cent is added to the formula to allow for time required in sharpening chisels, and 5 per cent is added to total time to allow for minor operations not common to all jobs.

Inspection:

Castings should be as clean, free from scale, sand, rough spots or sharp projections or irregularities in design as is consistent with shop practice. Chipping to fit should be in accordance with desired utility.

Payment:

Standard time on a 2-week pay period basis.

Approved:

Time-study Supervisor	Time-study Department

PART III

ORGANIZING FOR TIME STUDY WORK, WAGE PAYMENT PLANS AND JOB ANALYSIS

CHAPTER XXXIV

ORGANIZING AND SUPERVISING A TIME-STUDY DEPARTMENT

The magnitude of the problem of organizing a department for carrying on time-study work in a plant will depend largely on the size of the plant and on the length of time within which it is desired to have a fully developed department capable of handling all the time-study requirements for the entire plant. Small plants having less than several hundred persons engaged in productive work will doubtless find it more desirable to start out with but one well-chosen time-study man, who will be required to make his own place in the organization and develop his own detailed methods and system of records, guided by his previous experience and such available written matter on the subject as can be made applicable to his conditions. For the sake of uniformity, the discussion to follow on organizing and supervising a time-study department will be based on the assumption that the plant or department of a plant is of sufficient size to warrant a force of at least a half-dozen time-study men under the supervision of a time-study foreman or supervisor.

Qualifications of the Supervisor.—The first step to be taken by the management is to select the man to place in charge of the work. It is conceivable that a man without time-study experience could successfully develop a good organization, but, other things being equal, the experienced time-study man will undoubtedly do it much more easily. In addition to technical ability, he must know how to handle men of high caliber.

The time-study supervisor must also be more than a good time-study man. He should be well grounded in the fundamentals of factory organization. He must understand the functions and working principles of cost analysis, production scheduling, and planning, and he must be able to coordinate the work of his department with that of these just mentioned and other similar manufacturing activities. A thorough knowledge of the equip-

ment and manufacturing methods allied to the industry is also highly desirable, if not essential. He must have those personal qualities which command the respect and confidence not only of his own men but also of the rank and file of the line organization. He must be able to "sell" himself and his plans to the shop executives and supervisors, and to see beyond his own immediate duties in connection with time-study work to those things which are for the general good of the whole plant. It should be one of the duties of the time-study supervisor to study and offer suggestions on plant and departmental layout of equipment and manufacturing facilities in general.

Locating a Competent Man.—A very large plant, in which time-study work has been organized and is functioning in departments other than the one which it is now desired to organize, will have a field of trained men to draw from and should have no great difficulty in selecting a supervisor for the new department. The small plant, however, in which no time-study work has been done previously, has a very different problem. It is hardly likely that there will be a man in the employ of the company who is fully qualified to handle the work. There are several outside sources of supply, among which are:

1. Other plants.
2. Consulting engineering organizations.
3. Technical schools.

The three sources suggested above are, in the authors' opinions, named in the order of their importance, although there are advantages and disadvantages in each. A man who has done successful time-study work in one or more other plants has the advantage of practical experience. He has been a part of a regular factory organization more or less permanently. He has had to make good on his merits, without any special assistance from the management, as is generally the case with members of consulting engineering concerns. The fees of the latter are generally rather high. The management, when retaining such people, expects quick results and therefore gives them special attention and support by instructing its regular organization to give full cooperation and assistance. Such men, therefore, are not so accustomed to meeting opposition from the rank and file. Men employed in other plants, however, have the disadvantage of their experience being limited to one or, at best, a very few places, while the consulting engineer is more likely to

have a broader training in the methods and conditions of various industries.

Recent graduates from technical schools from courses in factory management or industrial engineering would hardly be competent to handle the responsibilities of organizing and supervising time-study work even though their theoretical training might be adequate. Their lack of practical experience in handling men would generally be too much of a drawback. Many of the technical schools, however, keep in contact with their graduates located in the industries and are frequently able to recommend competent men who are available. Other ways of reaching the right men are through advertising in technical journals, by personal inquiry, or through the employment bureaus conducted by many of the engineering societies.

Place in Organization.—The time-study supervisor, being in charge of a staff activity, should report to the executive head of the plant. To make him subordinate to the departmental executives would handicap him in his work, since it would be more difficult to secure the consent of the head of the department to changes in methods, equipment, or organization, which might, in the opinion of the department head, have a detrimental effect upon production, increase expense, or in some other way work to a temporary disadvantage.

Establishing Policies.—Once the man to take charge of time-study work is selected, his first duty should be to work out and submit to the management for discussion and approval the general policies to be followed in carrying on the work. In doing this, the status of time-study men with respect to other supervisors in the organization should be considered. For instance, the relation between the inspection department and the time-study department should be established. The information and assistance that each can secure from the other should be clearly outlined, and instructions necessary to guarantee that this established relation will be maintained should be issued. The same thing should be done with regard to the planning, scheduling, cost accounting, time keeping, payroll, and all other departments or persons that will be influenced or aided by time-study work.

Standardizing Methods.—It is well known that there are frequently a large number of ways of doing things to accomplish the same results. This may be said of time-study work, as of

many other things. There are but a few recognized time-study systems that are really different fundamentally, but there are countless slight variations in the ways that these systems are applied, depending, of course, upon the individuals who are applying them and upon local conditions in general. Some of these systems have been touched upon briefly elsewhere in this book, and each has its advantages and disadvantages.

It will be the duty of the man in charge of time-study work to determine and establish the detailed methods that will be employed. He will decide upon and recommend to the management the fundamental time-study system to be used and then adapt it best to fit the peculiar local conditions of the plant. Instructions for standard procedure should be carefully drawn up in writing and approved. It will also be the duty of the time-study supervisor, in the absence of a constituted training plan, to see that the members of his force are properly instructed in this standard procedure.

Establishing standard method of procedure calls for consideration of the method to be employed in reading the watch and of recording readings. For instance, shall it be the continuous method or the snap-back method, both of which are described and discussed in Chap. VIII? This also involves the question of the kind of watch to be used. Shall readings be recorded vertically or horizontally? One must give thought here to the design of the time-study form.

Another point of prime importance is that of determining the standard and subsequently the allowed time. Shall it be by the leveling method, as fully discussed in Chap. XIII, or shall it be one of the several other conventional methods of earlier development?

Some thought must be given as to how skill, effort, and working conditions are to be taken into consideration. A plan must be decided upon for taking care of allowances. Methods for recording and using information and data relative to the job must be determined. All of these and many other features of time-study procedure are discussed fully in Part I of this book.

After determining standard procedure for time study proper, the question of using most advantageously the data so secured will arise. As previously pointed out, there are a great many advantages in establishing time values by means of formulas. If this practice is to be followed, detailed methods for formula

construction and application must be worked out, for which the reader is referred to Part II of this book.

Forms and Equipment.—The most important of the necessary forms is the time-study sheet which should be designed, or adapted from existing designs, so as best to suit local conditions and the methods of procedure agreed upon. Other forms and equipment such as the watch and time-study board should be secured or made best to suit requirements.

Personnel of Department.—As the building up of the force progresses, it will generally be found that there are places for two types of men; those who are to be strictly time-study men devoting their time to time-study observation and formula construction, and those who do the routine work of establishing time allowances from formula or time-study data. The average time-study department will also have sufficient clerical and stenographic work to justify the employment of a girl who can serve in such a capacity.

Records and Systems.—It will be necessary to determine what records should be kept and how data shall be classified and most conveniently be made available for use. A routine for determining and recording time allowances should be established. A relation should exist with the scheduling department so that the time-study man may know when time values are required, thus enabling him to plan his work to meet current demands and keep up to date. Someone must be designated to have charge of the reference files and the giving out of time allowances. This can generally be handled by the time clerk or by the clerk in the time-study department. A plan for keeping all original data and time studies properly classified and filed should be developed, keeping in mind the availability for reference.

CHAPTER XXXV

STANDARDIZING TIME-STUDY METHODS AND TRAINING TIME-STUDY MEN

In general, wherever there is more than one person engaged in doing the same thing, there will be more than one method of doing it. The degree of difference may be small or great, depending on the number of persons engaged. Quite often this difference in method is a very good thing, especially in the case of something new, as each method will usually have some good features. Perfection is the result of considerable experimenting and the combining of ideas. There are, however, many cases where a difference in method does more harm than good, and such is the case in time-study work. Lack of standardization of methods in this line leads to inconsistency, which inevitably breeds suspicion and dissatisfaction.

Reasons for Standardizing Time-study Methods.—Throughout this book, standardization has been repeatedly referred to as being highly desirable, if not actually essential. It is agreed that standard working conditions, standard materials, standard equipment, and standard methods of performing the work to be studied will aid greatly in making reliable and accurate time studies, to say nothing of the increased value of the studies themselves for the purpose of comparison. If it is well to standardize the things to be studied, it should be readily apparent that it is also well to standardize the methods for making the studies and for carrying on time-study work in general. This is especially desirable in a large plant where a comparatively large number of time-study men are employed. In such a plant, the time-study organization is frequently divided into groups, each group looking after a separate department or division of the work. Leading each divisional group is one who is known as time-study foreman or time-study supervisor. Consistency and standardized methods are desirable between men in the same division and also between divisions. The men from one division should be able to talk in common terms to the men from another throughout the entire

works. As far as possible, they should be trained to use the same standards in judging what constitutes a given degree of effort, skill, or conditions.

Standard Procedure.—In order to establish and to maintain standard time-study methods and in order to standardize judgment and knowledge in connection with time-study work, it is necessary to decide on and adopt one standard procedure which is to be followed at all times. This can best be done by a committee consisting of from four to eight of the best time-study men in the organization. In smaller plants where only a few time-study men are employed on time-study work, all of them may be on the committee. This committee should decide on a procedure which will be written up and bound and distributed to the time-study supervisors to be used by them in deciding all questions and for instructing new men.

The standard procedure write-up should give the general principles of time study and the establishing of time values. It should give detailed instructions on how to make and work up a time study, and it should contain a table of allowances covering all conditions and explain how they were derived. The procedure to be followed in constructing a formula should be explained, including detailed instructions on how to make the formula write-up. The system of recording and filing time studies and formulas should be thoroughly explained. In writing up a standard procedure, this book will serve as an excellent guide. In fact, the standard procedure will contain the same information in the same order but in very much condensed form.

Suggestions for improvement of time-study methods should be encouraged, but no change should be adopted nor any deviation allowed without the approval of the standardization committee. The committee should hold regular meetings to act on suggestions and to discuss the success with which the established procedure is functioning. In case any change is adopted, no matter how slight, it should be done in an official manner, and all copies of established procedure should be corrected immediately.

Maintaining Standardized Methods.—It is one thing to decide on standard methods of doing things and another to have them carried out. In small plants where only a few men are employed for time-study work, it is not so difficult to keep methods standard, but the larger plants have more time-study men and therefore have greater difficulty in maintaining uniform methods.

Standardization is best maintained in the larger plants by having regular meetings of all time-study foremen in which standard methods of procedure are discussed. In addition, each time-study foreman should call periodic meetings of the men under him in which he should pass on what was discussed at the meeting of the foremen. Such meetings keep alive the interest in maintaining standard methods, and they also serve to draw forth suggestions on ways of improving the standard procedure.

Training New Time-study Men.—When new men are taken into the time-study department, it is essential that they be thoroughly trained in time-study methods and practices. The damage that can be done in a short space of time by an untrained man has already been pointed out, and no further elaboration is necessary. Since it usually requires several months to train a new time-study man properly, the advantages of having this training done at a centralized place and in a uniform manner by someone who is fitted for the work will be readily apparent.

Without a training department, the entire responsibility of training new men rests upon the time-study foremen. Without reflections upon the ability of these men, it will be realized that such conditions will not permit the best results. In the first place, each foreman will be inclined to use his own methods and to follow no really standard procedure. His regular duties make it impossible for him to spend a great amount of time with the new man. Ordinarily, he places the recruit in the hands of one of his older experienced men, which means additional work for the older man, since the new man actually hinders him in the performance of his regular work. There is seldom a prearranged schedule, which condition results in many important points being slighted. Generalities are dealt in to a great extent, and troublesome and elusive details are left for the new man to discover and clear up as best he can. Instruction periods are likely to be irregular, and, in general, the new man does not clearly visualize his place in the organization nor exactly what is expected of him.

Selecting the Instructor.—When the need of centralized training is felt and it is desired to organize such an activity, certain definite preliminary steps are necessary. First, someone must be selected to take charge of the instruction work. He must, first of all, be an expert time-study man himself, and,

second, he must possess instructing ability to a marked degree. Whether he shall devote his entire time or only part time to the work must be dependent upon the size of the organization and the demand for his service. A small plant employing but a few time-study men would not be justified in having a man of the caliber required for this work doing nothing else. Under such conditions, the better plan is to select one of the best of the regular men and have him arrange a schedule to provide for a certain number of hours daily to be devoted to instruction work. A large plant, on the other hand, employing 50 or more time-study men, can well afford to have one man fully employed at this work.

It has been found by experiment that work of this nature cannot be effectively handled according to classroom methods. The tutoring plan, however, has been found very satisfactory. It must be remembered that fairly high-grade men are being handled and they cannot be treated like school children. While a man might be reluctant to display his lack of training or other weaknesses in the presence of others, an instructor or tutor handling each individual case privately may have no difficulty whatever in awakening a genuine interest in the man's mind. Much depends, of course, upon the personality and tact of the instructor. He must have the absolute confidence of the pupil, and to gain this, he must make the man feel that the details of what passes between them will be regarded as confidential.

It should be understood that the detailed methods suggested herein are not offered as the best and only ones. Each individual instructor should use the methods which he can employ most effectively. This should serve as a guide, however, as regards the subjects taken up. Whatever the methods employed in teaching the details, the instructor must be sure that each detail is clearly understood by the pupil before going on to the next.

It is essential that this training business be made a part of the day's work and that a schedule be followed in order to insure covering the ground fully. The different subjects should be taken up in logical order, making sure that one is mastered before going on to the next. Instructor and pupil should "get on to common ground," so to speak, avoiding anything that suggests the formality of school.

Time-study Procedure.—Before asking the student actually to make time studies, it is suggested that Part I of this book,

which is virtually a standard time-study procedure, be thoroughly studied. This should be supplemented by personal instruction in the use of the watch. Its operation should be explained by actual demonstration, and accuracy in reading it should be checked by observation.

After thoroughly reviewing the text and technical principles in connection with making time studies, an operation with which the student is familiar should be selected for practice studies. Ordinarily for the first study, the man should be thrown entirely on his own resources, from the analysis of the job and division into its elements to the observations and calculations. This is done primarily to discover just how much has been absorbed by the student from the written instructions. This first study should be criticized closely by the instructor, and all departures from recognized standard practice pointed out with suggestions for correction.

In order to check accuracy of reading the watch, the instructor and the pupil should each make a time study of the same operation simultaneously. Both watches should be started at the same instant and the study continued over the same period. Assuming that the instructor's study is nearly perfect, it may be used as a standard against which the other may be checked, reading for reading. A check of the elemental elapsed times will be better than a check of the watch readings, for a slight difference in starting the two watches would introduce a constant error throughout the study equivalent to the amount of the difference and at no place would the readings coincide, even though the actual elapsed time might be the same. It can be seen from these studies whether the student reads ahead or behind the watch and whether or not he is consistent in his errors if such exist. All practice studies should be checked carefully until very little if any departure from standard procedure can be found. The ultimate good is not accomplished by merely calling a man's errors to his attention. One should be sure that the pupil understands the correct way to overcome his errors. This should be continued until the instructor is satisfied that the student is able to make reliable time studies.

Formulas.—When the man can make dependable time studies, a simple operation on a common line of work should be selected for the formula instruction. He should secure time studies on numerous sizes and kinds of pieces or classes of jobs under

varying conditions. Extreme as well as average jobs should be included when selecting work to be studied. Adverse as well as favorable conditions should be considered, and studies should not be confined to one operator if possible to get studies on others.

When sufficient studies have been made, the instructor should personally assist the man in constructing the formula, step by step, in accordance with the principles of formula construction as described in Part II of this book. The reason for each conclusion should be fully explained and the influencing factors pointed out, as well as how those influences and their extent is determined.

For this sample formula, the instructor should go through every step in order to be sure that the student has a clear understanding, so that he can be depended upon later to make up reliable formulas without assistance. If a man is to be expected to do things the same way each time, he must first be taught that one way in every particular.

Conclusion.—Unlike industrial training methods frequently employed, in which men are required to attend lectures and group meetings for the discussion of subjects of general interest, each man's case is given individual attention, and his greatest needs are emphasized most. This method of instruction is arranged so as to parallel the student's daily work and yet not interfere with it. The general principles which have been adopted as standard practice are illustrated by applying them to the work and operations in the specific department where the man is employed.

CHAPTER XXXVI

WAGE-PAYMENT PLANS

Time values established by time study and formula should be applied under some incentive system of wage payment if they are to be used to the best advantage. Occasionally, time values are used merely for estimating purposes, and the work is done on the straight day-work basis. The value of such estimates is questionable, for the workman, lacking incentive, is not likely to meet the estimated time. These time values do, however, tell the foreman what he may expect in the way of production, but without an incentive system, considerable driving is necessary to get it.

A number of good incentive plans have been devised, and it is beyond the limits of this book to examine the merits and demerits of each. They are all based on certain fundamental principles and vary only in minor details. It will be well, then, to examine the characteristics that a good incentive system should have and later to see just how several of these systems attempt to gain them.

Characteristics of an Incentive System.—To secure a reasonable effort on the part of the workers, the system under which they work must provide a reward in the form of increased earnings. In other words, as a man increases his production, his earnings must also increase.

A new man learning a job or an older man working under adverse conditions will not be able to turn out what is recognized as an average amount of work. If his production falls considerably below normal and he is paid on a system similar to straight piece work, his earnings will suffer accordingly. If this continues for any length of time, the pay envelope will be seriously short. No man likes to work with the continual fear of his earnings falling far below average. The best incentive systems, therefore, provide a minimum guaranteed rate below which it is not possible to fall. This adds greatly to the feeling of security on the part of the worker, and it enables new men to earn a living

wage while learning the job without the necessity of establishing instruction periods as such. The guaranteed rate should be the recognized rate which is paid in the local industrial community for that class of work. This will make it possible to hire new men easily, and it will enable the supervisors to ask the man to work on a day-work basis at any time without penalizing him. He is hired at a rate which is recognized as being right for that class of work. Wherever possible, the management gives him a chance to increase his earnings under its incentive system, but when development and other jobs on which no time values can be established come along, the management has a perfect right to expect the man to do them at his guaranteed rate. Any system which uses a low guaranteed rate as a spur to greater efforts does not have the above very important feature.

The system should be such that it is easy for a man to compute his earnings. Any involved system that the workman cannot understand tends to decrease the incentive offered. If the workings of the system are more or less mysterious and unfathomable to the worker, he tends to get the feeling that the management will pay what it likes regardless of what he does. He will realize, of course, that his earnings will increase with greater output, but if he does not know the manner in which they increase, he is likely to feel that the management is not paying him all that is coming to him. Systems where earnings increase in direct proportion to output are, therefore, more desirable than systems which make use of a sliding scale, although there are, of course, other points to be considered.

Summing up, the main characteristics that every incentive system should have are a reward for increased effort, a minimum guaranteed rate, and understandableness. It will be well to examine several of the better-known incentive systems and see whether or not they have the above desirable characteristics.

Piece-work Plan.—The straight piece-work plan was the first incentive system to be used. A worker is paid a definite amount of money for each piece produced, and his earnings are solely dependent on the amount of work he turns out. This system gives a reward in direct proportion to effort, and it is very easy to understand. It does not, however, guarantee a minimum wage, and hence the worker is severely penalized by adverse conditions. From a clerical standpoint, piece work is easy to apply as long as basic wage rates remain the same, but when they change, it is

necessary to revise every piece rate that was in effect. To overcome this disadvantage and also a certain bad psychological effect on the worker of having rates expressed in money, the 100 per cent premium plan was devised. This plan is identical in every respect to the piece-work system except that rates are expressed in time instead of cents. Thus, where under the piece-work system a man would produce 100 units at a piece-work rate of 1 cent per unit, under the 100 per cent premium plan he would produce 100 units at, say, 1 minute per unit. In the first case the man would earn $1 and in the second, he would earn 100 minutes. If his base rate were 60 cents per hour, in the second case he would also earn $1. The advantage of expressing rates in time instead of in money is readily apparent when it is realized that a unit of time is fixed regardless of prevailing wage scales. Therefore, in order to effect a change in earned rates in accordance with changing conditions, it is necessary to vary only the base rate of each worker. The established allowances on all jobs in the shop will remain constant as long as manufacturing conditions are unchanged. The vast saving of clerical labor at a time of change is obvious. Aside from this, the 100 per cent premium plan has no features, good or bad, not enjoyed by the piece-work system.

Halsey Premium Plan.—The Halsey Premium Plan guarantees a minimum day rate and offers as an incentive a certain fraction of the amount of time saved by the worker from the allowed time. The system is easy to understand, and therefore has all of the characteristics of a good incentive system to a degree. The reason for giving the worker only a part of the time saved, generally from one-third to one-half, is because it is felt that by increasing his production, he is using more power and is harder on tools, equipment, and the like. Since these are furnished by the employer, it is felt that he should have part of the time saved to compensate him for this additional expense.

The guaranteed rate under this system is usually low, and it penalizes severely the worker who fails to better the allowed time. The low guaranteed rate also makes it hard to hire new men. Under this plan, the time values established are usually generous, and it is quite possible for the average workers to make double time. Thus the incentive offered is high. The fact that the worker gets only part of the time saved tends to prevent excessive earnings. Workers coming from other plants

where earnings vary directly with output are likely to feel that they are entitled to all of the time saved. This idea spread among the older workers is likely to lead to discontent.

Taylor Differential Piece-rate Plan.—Dr. Frederick W. Taylor devised a plan whereby the worker was paid a certain rate for each piece if he equaled or bettered a standard production and a much lower rate for each piece if he failed to do so. The production which was to be considered as a standard was carefully determined by time study. This plan is exceptionally severe in its penalty when a worker fails to meet the required production, and conversely, it offers a high incentive to produce as much as possible. It involves more clerical work at such times as it becomes necessary to revise rates than does the straight piece-work system and more clerical work in making up the payroll in everyday application. Aside from these features it differs little from the straight piece-work system in either good or bad points.

Gantt Task and Bonus Plan.—The Gantt Task and Bonus Plan guarantees a minimum wage. It establishes by careful time study standard tasks. If the worker fails to perform the task in the allowed time, he is paid for the time he works at a fixed rate per hour. If the task is performed in the allowed time or less, a bonus in time is added to the allowed time all of which is multiplied by his rate.

Standard Time System.—A variation of the Gantt Task and Bonus Plan is known as the Standard Time System, in which the worker is also paid his guaranteed rate when he fails to do the job in the allowed time or less. If he meets or betters the allowed time, he is paid for the number of hours he makes at a higher rate per hour. This plan then guarantees a minimum wage, it offers an incentive to increased effort by varying earnings directly with effort, and it is easy for the worker to compute his own earnings. Thus the plan has all of the essential characteristics of a good incentive plan.

The difference between the low or day-work rate and the high rate may be made as great as is considered proper at the time the system is installed. If the difference is great, the incentive is high, but the worker is penalized heavily for failure to meet the allowed time, and hiring new men is difficult. If the difference is small, the converse is true. Experience has proved, however, that even if the high rate is but 10 per cent above the low, the

incentive is sufficient to spur the worker on to his best effort. At the same time, the difference is not so great that the worker suffers any great hardship if he fails to meet the allowed time for several days, and it is possible to ask him to work day work without penalizing him, provided that the day-work rate is the recognized rate for the class of work he is doing. This plan has been very successful within the experience of the authors, and appears to have few disadvantages.

Other Systems.—The incentive plans discussed thus far have all given an increased reward in direct proportion to increased output, but under certain other systems, earnings and output do not vary according to this straight-line relation. The Emerson Efficiency Plan, for example, sets a certain standard of performance and then gives a bonus based on the efficiency of the operator calculated by dividing time taken by time allowed. Below 60 per cent efficiency no bonus is given, and the operator receives only his guaranteed rate. Above 60 per cent, the bonus increases with efficiency according to a sliding scale which provides increasingly high bonuses with each increment of increased output. Thus a high incentive is furnished, and the workers will generally produce as much or more just before quitting time as they do during the day, for they realize that they are receiving more and more for each additional unit they can turn out. Under this plan, the tendency to slow down just before the whistle blows is minimized.

The Rowan Plan provides increased earnings in just the opposite manner from the Emerson Efficiency Plan. The bonus paid is highest immediately after standard performance is met and becomes increasingly smaller for each additional increment of output. This is accomplished by computing the bonus by the formula,

$$\text{Bonus} = \frac{\text{time allowed} - \text{time taken}}{\text{time allowed}}.$$

As the time taken approaches zero, the bonus approaches 100 per cent. Thus the worker's earnings are limited to double his guaranteed rate and actually are always lower. Little incentive is offered for increased production shortly after standard performance has been met. This plan is not much used in this country, but has found favor in England where the idea of restricted output is so prevalent.

Figure 59 shows the way earnings increase with output for each of the plans mentioned above. These incentive plans are generally recognized as being the classics of their line, and all other systems are merely modifications of them. Hours are used as the basis when establishing standard performances in

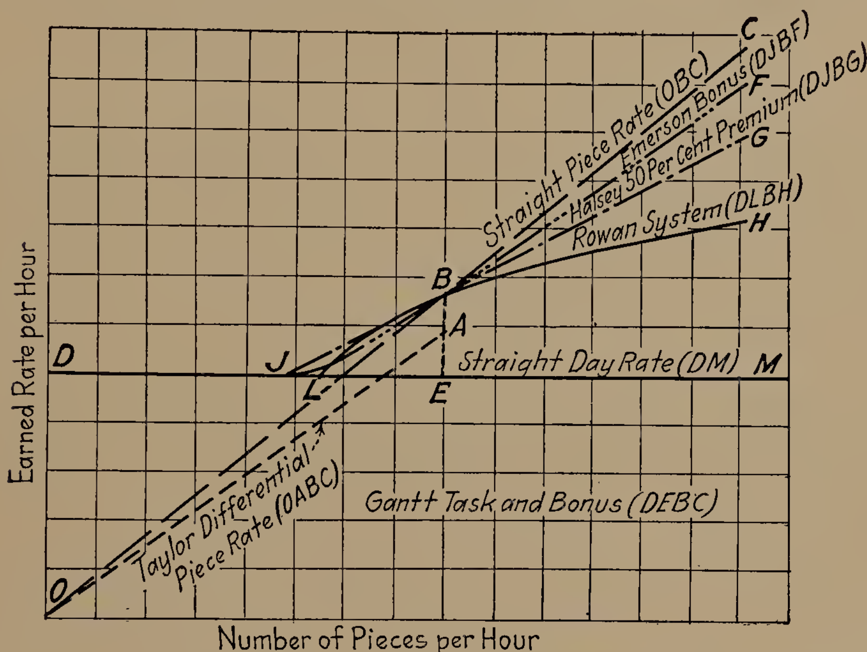


FIG. 59.—Curves showing the way earnings increase with production under some of the recognized wage payment plans.

most incentive plans, although some industrial engineers have devised units of their own. A more complete discussion of wage-payment plans than is here advisable may be found in "Industrial Organization" by Kimball, in the pamphlets brought out by the American Management Society in 1925, and in the writings of the devisers of the systems.

CHAPTER XXXVII

THE GROUP SYSTEM OF WAGE PAYMENT

The results obtained from incentive systems have been remarkable, but there are, at the same time, some disadvantages which occur from having a number of workers concentrating only on their own individual production. Each worker realizes that he is paid only for what he produces, and it is but natural that he should strive to increase his own output, regardless of all else. He feels that he has no time to help out new men or to give a fellow worker a hand when he is in difficulties, and he is unwilling to spend time hunting lost material, doing a little extra work for which he is not paid directly but which will improve quality, speed up work as a whole, or help out the supervisory force.

In order to correct such conditions, the group system of wage payment has been devised. That it has accomplished its purpose has been proved by successful application in many and varied lines of industry. The group system may be used with any good incentive plan. A complete exposition of the fundamental principles upon which the group system is based, together with a discussion of its advantages and disadvantages, may serve to point out how the group system may be successfully applied to work which has previously been done on the individual basis.

What the Group System Is.—When work is done under an incentive plan, each operation performed in the making of a piece of apparatus has either a time or a money allowance, depending upon the particular system used. The earnings of each worker depend directly upon what he produces.

Assume that two workers of about the same degree of skill and working with the same effort work side by side on the same class of work. They notice that although they work in about the same manner, they do not produce equal amounts of work each day. One will produce more than the other, depending upon the conditions met with. One may run out of material, may be delayed by tool breakage, or may experience any of the

thousand and one delays which occur occasionally. The other man, in the meantime, is having a better run of luck, and he is able to produce more on that particular day. These two men, wishing to steady their daily earnings and to secure the fullest cooperation from each other, mutually agree to pool the work done by each and, at the end of each day, make an equal division of the total. These operators, then, have formed a group. This same agreement may be made among three, four, or any reasonable number of men. When a group is formed by the men themselves, however, the number of members of the group is generally kept small, for the arrangement usually calls for an equal division of earnings, and only men who are capable of producing nearly equal amounts of work are willing to band together.

Groups formed by the men themselves occur in industry, but they are not common. Generally, workers on the same class of work possess different abilities, and the greater producer is not willing to enter into an agreement with the lesser producer. Rather, groups are organized by the management, and a payment system devised whereby each man shares in the earnings of the group in proportion to the amount of time he works in the group and—which is not done when the men themselves form the group—in proportion to his ability.

A group, then, is a number of workers doing the same class of work who pool their entire output, and the method of distributing the earnings of the group among the workers is known as the group system of wage payment.

ADVANTAGES OF THE GROUP SYSTEM

Better Cooperation.—There is greater cooperation among men in a group than among individuals. Since everything that will aid in the completion of the work will mean more money for the group and hence for each man, the individual is willing to help his fellow workers whenever necessary. For instance, if a man needs help in lifting a heavy casting onto his work bench, he will get that help under the individual incentive system only when his neighbor has finished what he is doing and when it suits his convenience to give a hand. Help is given grudgingly, and there is continual wrangling between the men, particularly if they do not happen to like each other for personal reasons. In a group, one man will set personal feelings aside to help another

man willingly, because, by so doing, he knows that he is helping to increase his own earnings as well as those of the other man. This willingness to cooperate with one another increases with the length of time the group has been working together, until a group spirit is built up which will affect every man in the group.

Lost time caused by waiting for a move man to bring more material, waiting for the tool room to grind tools, and other small delays which would cause the individual operator to lose time is practically eliminated under the group system. If the operator is forced to stop his own work for any reason, he will help another man in the group on another operation, or he will do some odd job which will aid the group as a whole.

Again, one man will be more careful in performing an operation if he knows it will aid another man in performing the following operation. For example, one man milling a casting which is next to be drilled will try harder to remove all burrs so that the piece will fit smoothly into the drill jig of the next man. If any burrs must be filed off, he will do it while his machine is making the next cut. Thus the drill-press operator can work steadily with no lost time. Such things, although small in themselves, amount to considerable time in the aggregate and will increase the overall group efficiency and eonsequent earnings to quite an appreciable extent.

There are always some jobs in a given class of work which are not so desirable from the worker's viewpoint as others. The work may be heavier or more complicated than the average, it may be more disagreeable, or it may be a short order which will not allow the worker to get into the swing of the work and thus work more efficiently and make higher earnings. No matter what the cause, if the job is undesirable, under the individual system, there is a tendency for the operator to shun it in the hope that eventually some other worker will do it. This makes it more difficult for the planning department to get such jobs through the shop, and often these orders are seriously delayed. A group, on the other hand, realizes that it will eventually do the job and that there is no particular advantage in setting it aside and favoring other work. Thus, the schedule clerk has merely to inform the group leader of when the job is wanted to be reasonably sure of getting it. This materially lessens the work of the planning department, and it tends to reduce the number of overdue orders.

Reduction of Supervision.—Many workers object to so much being spent for overhead, for they feel that they are supporting the so-called non-productive employees. This feeling is minimized under the group system, for the amount of supervision, and hence the size of the non-productive supervisory force is greatly reduced. The group leader is, in effect, made an assistant foreman. He is, however, in much closer contact with the men under him than the assistant foreman would be, for he generally has fewer men to handle, and he works side by side with his men. The group leader is personally interested in what his men produce, for their production affects his earnings, while, as a rule, assistant foremen are paid on a fixed-salary basis independent of production.

The group leader gives instructions to his men and sees that they work properly. He makes certain that they are using the most efficient methods and that they interpret drawings and shop information properly. The foreman merely instructs the group leader in a general way, leaving to him the working out of the minor details.

The size of the planning department is reduced by the group system. Instead of assigning jobs to each individual man, it tells the group leader what jobs are wanted next and leaves it to the group leader to get the jobs done. Obviously, it is easier for the planning department to deal with 10 group leaders each of whom supervises 9 men than it would be to deal with the 100 men separately.

Training New Men.—Under the group system, few instructors are needed. The group leader and the other men in the group all help to show the new man how to go about his work more efficiently. The new man tends to learn from members of the group in a shorter period than he would under an instructor, since they are in more constant contact with him. The older men realize that the sooner they break in the new man, the sooner they will get the full advantage of his efforts. The new man is anxious to show the group that he is capable of working with them; so he strives more earnestly to learn than he would under an instructor. The method of paying a new man so that the group does not have to bear the entire burden of the unproductive learning period is explained in a later paragraph.

Reduces Non-productive Labor.—Under the group system, it is often possible to include in the group material handlers and

other service men so that they may share in the efforts and earnings of the group. For instance, suppose that one man is needed to bring materials to and remove finished work from a group of 10 men. By increasing all time allowances or piece rates applicable to the group by 10 per cent, it will be possible to include the move man in the group. His wages will then be taken out of the overhead expense and included in the productive labor. His earnings are affected by the group, and hence he will be more willing to help them as much as possible. The group leader will be quick to find simple jobs for him to do when he has no material-handling work to occupy him. In time, this man will be able to learn to do the harder jobs, and eventually he may be able to take his place in the group as a full-fledged artisan and, of course, will share in the earnings of the group to a greater extent. The service men, as a whole, will realize that they have a chance to improve themselves and get ahead, and it will be possible to get a better class of men to accept and keep such jobs. Labor turnover will be reduced, and at the same time, new skilled workers are constantly being developed.

During the day, it is necessary for an individual worker to spend some little time in making trips to the storeroom, tool room, timekeeper's office, production office, and drawing file, often several times a day. The time spent by 10 individuals in one day on such trips will amount to a surprising total.

In a group, the group leader does most of this, and he is able to plan so that only one trip is necessary where four or five were made before. If three men will need tools within the next hour, the group leader can get them in one trip. Where a time slip is handed in each day, the group leader will take the slips for the whole group to the time keeper in one trip. With trip time reduced, production time is increased, the individual workers can earn more, and the cost of production is reduced.

More Accurate Costs.—Under the individual system where the worker is guaranteed a minimum day wage regardless of what he produces, for various reasons, he often adjusts his time among the different orders upon which he has worked. This tends to give inaccurate costs. Under the group system, this adjustment of time is not possible. The group does not turn in time against any one job but merely the number of hours worked by the group during the pay period. They are paid on what they actually

produce as taken from the shipping report of the inspector who handles the work of the group.

Advantageous to Time-study Department.—As a rule, the group leader is a man of somewhat higher mental caliber than the other men in the group. In most cases, that was one of the deciding factors in selecting him for the job. He is better able to reason and is more able to realize the soundness of arguments which are presented to him. Thus the time-study department finds it easier to deal with him.

The other men in the group deal with the time-study man through the group leader. If they have any complaint to make about the job allowances, they bring it to the group leader. Often it goes no further, for the group leader is able to explain just what the reasons are for certain things which may appear to be puzzling on the surface. On the other hand, if the group leader feels that they have reason to complain, he takes up the matter with the time-study department, not on the spur of the moment, but after carefully weighing the merits of the case. The group leader knows that if the time-study men are in the wrong, they will be the first to admit it, and if not, that they will go over the matter willingly and try to straighten his mind on the point. Such a condition promotes harmony and close cooperation between the men and the time-study department. Calm analytical discussion promotes understanding just as surely as blind heated controversy kills it.

The actual work of making time studies is also made easier, for there is confidence between the group leader and his men and between the group leader and the time-study man. The group leader is constantly looking after the interests of the group. If extra work must be done for some special reason, he does not hesitate to bring it to the attention of the time-study man. The time-study man does his part in seeing that such cases are handled in the proper manner; that is, he either allows a special value to cover the extra work if that value can be determined intelligently, or allows them to do the extra work as day work.

Simplifies Costing.—Where actual costs are determined on every job that goes through the shop, a very large cost staff is required under the individual system. Each man that works on a job turns in an individual time slip on that job. When the job is completed, all the time slips are assembled. The amount paid each worker on each time slip is found by multiplying the

time earned or the number of pieces made, as the case may be, by each individual rate. The total of these amounts gives the actual labor cost of the job. If the job comes through the shop later and is worked on by different men at different rates, the actual cost will be different. If a breakdown occurs while the job is being made and the worker neglects to turn in an extra time slip covering the delay, the job will be charged with the time lost, while in reality it does not deserve this charge. Thus costing under the individual system is complex, inconsistent, and inaccurate.

Under the group system, the cost is computed from the average wage rate of the group multiplied by the total time allowance for the job. This makes a very simple method of costing. Unless the personnel of the group changes or unless there is an increase or reduction of wage rates in the group, the cost of making the job will be the same every time it goes through the shop. Minor breakdowns are not charged against any one job but are distributed over all jobs.

Simplifies Timekeeping.—Timekeeping is made much easier under the group system. Each man turns in only one time slip a day. On it are his name, check number, group number, and the amount of time worked. The amount of time earned is figured from the shipping report of either the section or the group as made out by the inspector. Thus the timekeeper has only as many time slips to handle each day as there are men in the group.

There is another method which is often used and which amounts to practically the same thing. The group leader turns in a slip for each job completed. This slip is O.K.'d by the foreman and the inspector and constitutes the shipping report. The total time for the pay period spent by each man in the group is turned in by the group leader on the form shown in Fig. 60. This time is checked against the attendance report. Whether the time worked is turned in on separate slips and the shipping report on one sheet or the time worked on one sheet and the shipments on separate slips matters little. The amount earned is figured from the number of pieces shipped times the appropriate time values of job rates.

Under the individual system a time slip is turned in on each job worked. The amount earned must be figured on each individual time slip. If a worker is turning out a number of short orders, he may hand in as many as 20 time slips during the day.

Section F-12 Time Report Pay Ending

Patt. No.______ Total Limit______ Contract No.______ Group 1 7-31-25

	Check No. 1	Rate	Check No. 3	Rate	Check No. 5	Rate	Check No. 15	Rate	Check No 32	Rate	Check No. 39	Rate	Check No. 46	Rate	Check No. 47	Rate	Check No. 86	Rate	Check No. 134	Rate	Check No. 183	Rate
	Name Faulkner		Name Furbish		Name Dougherty		Name Ross		Name Schulte		Name Hepnarowski		Name Johnson		Name Ullum		Name Baldi		Name Henderson		Name Cline	
Date	Reg. Hrs.	O. T. Hrs.	Reg. Hrs.	O. T. Hrs.	Reg. Hrs.	O. T. Hrs.	Reg. Hrs.	O. T. Hrs.	Reg. Hrs.	O. T. Hrs.	Reg. Hrs.	O. T. Hrs.	Reg. Hrs.	O. T. Hrs.	Reg. Hrs.	O. T. Hrs.	Reg. Hrs.	O. T. Hrs.	Reg. Hrs.	O. T. Hrs.	Reg Hrs.	O. T. Hrs.
7-16	8^2		8^2		8^2		8^2		8^2		8^2		8^2		8^2		8^3		8^3		8^3	
17	8^2		8^2		8^2		8^2		8^2		8^2		8^2		8^2		8^3		8^3		8^3	
18	4^1		4^1		4^1		4^1		4^1		4^1		4^1		4^1		4^1		4^1		4^1	
20	8^2		8^2		8^2				8^2		8^2				8^2		8^3		8^3		8^3	
21	8^2		8^2		4		8^2		8^2		8^2		8^2		8^2		8^3		8^3		8^3	
22	8^2		8^2		8^2		8^2		8^2		8^2		8^2		8^2		8^3		8^3		8^3	
23	8^2		8^2		8^2		8^2		8^2		8^2		8^2		8^2		8^3		8^3		8^3	
24	8^2		8^2		8^2		8^2		8^2		8^2		8^2		8^2		8^3		8^3		8^3	
25	4^1		4^1		4^1		4^1		4^1		4^1		4^1		4^1		4^1		4^1		4^1	
27	8^2		8^2		8^2		8^2		8^2		8^2		8^2		8^2		8^3		8^3		8^3	
28	8^2		8^2		8^2		8^2		8^2		8^2		8^2		8^2		6		8^3		8^3	
29	8^2		8^2		8^2		8^2		8^2		8^2		8^2		8^2				8^3			
30			8^2		8^2		8^2		8^2		8^2		8^2		8^2				8^3			
31			8^2		8^2		8^2		8^2		8^2		8^2		8^2				8^3		8^3	
Total	93^2		110^2		106^2		102		110^2		110^2		102		110^2		84^2		113^2		96	

FIG. 60.—Group time report.

The much greater amount of clerical work that is necessary is readily apparent.

Quality of Product Is Improved.—Where incentive systems are in effect, it is often stated that quality is sacrificed for the sake of production. Whether it is or not is largely dependent upon the standards set up by the inspection department and the strictness, with which they are maintained. For a given set of eonditions, however, quality is improved by the installation of the group system. There is not the tendency to slight work either with the hope that it will not be traced to the responsible person or with the idea that someone else will do it later. The group as a whole is directly responsible for the quality of work produced. If one man in the group slights part of the work, another must make it up, and thus no one gains anything.

The group leader will try to divide up the work so that each man will always be doing the same kind of work. This tends to develop specialists within the group, and specialists will, because of their superior skill, turn out a better quality of work.

Very often a group working on assembly work or performing a number of operations on the same part takes a pride in its work which an individual does not. The individual does one or two operations on a piece and then loses sight of it. The group sees the work from the time it starts work on it until the time it is ready to ship it out. Quite naturally, it takes more interest in turning out a good job. A word of commendation from the management now and then to the group leader and other interested parties will tend to stimulate this pride of workmanship.

Checking Simplified.—Checking the production of the individual operator to see that he has actually done all that he turns in time for is no small task. Under the group system, it is not necessary to check each operation except in the case of groups that perform only one operation. The completed product as it is shipped from the group is all that need be checked. The number of checkers needed is reduced, and another item in the overhead expense is cut down.

Men Work More Conscientiously.—Each man in a group knows that the others expect him to work conscientiously, and he expects them to do the same. He realizes the justice of this, for he knows how he would feel if he saw another man in the group standing by in idleness while he was working.

Where work flows through a group, each worker performing an operation upon it and then passing it on to the next, each man feels that he is a sort of link in the chain of production. He realizes that his absence will retard the flow of work on that particular day. He knows not only that he will lose what he might have earned that day but also that his bonus for the pay will be reduced because the group on that day was less efficient. For this reason and out of consideration for his fellow workers, a man working in this kind of group tends to be more regular in attendance.

Wages Are Fairly Distributed.—The earnings of the group are pooled for a given pay period and are then distributed among the members of the group. The share which each individual receives is dependent upon two factors: first, the number of hours that he worked in the group during the pay period and, second, his value to the company. This latter is determined by his skill, length of service, attitude, intelligence, and general make-up. Thus each man receives payment in proportion to his value to the company. It is often said that the more skilled worker who can produce a large amount of work is working for the less skilled members of the group. The skilled man may produce the equivalent of a bonus of 50 per cent while others less skilled produce only 10 per cent but each at the end of the pay receives a bonus of 20 per cent. This is true, but the larger producer will have an hourly rate considerably higher than the other men and will draw a much larger pay. If the group as a whole exerts itself so that it increases its earned bonus to 25 per cent, the man with the higher rate earns more in proportion than the other men. Thus, it is justifiable to expect him to produce more than the other men.

An exaggerated numerical case may serve to show this more clearly. Assume that two men are working as a group and that one has an hourly rate of $1 while the other's rate is but half that. If, at the end of a pay period, they have earned a 10 per cent bonus, the first man will be paid at the hourly rate of $1.10 and the second will get 55 cents. Then if, by an increased effort, they earn for the next pay period a bonus of 20 per cent, the first man will receive $1.20 per hour and the second 60 cents. The first man receives an increase which is twice that of the second man, and it is but just that his increased effort should be twice that of the other man. Thus the better man is not working for

the poorer, but each is receiving just remuneration for what he produces.

Wages Do Not Fluctuate Greatly.—Wages from pay to pay are more nearly constant under the group system. When a man is working as an individual, a hard job or unusual delays may retard him so much as seriously to affect his wages at the end of the pay. Minor delays, small breakdowns, and a general run of hard luck may come all at once, and the fact that the next pay may be large due to a reversed situation does not make the slim envelope look any fatter. Under the group system, earnings are more nearly constant. Where one has bad luck, another has good luck, and the average of the group will be very nearly the same from one pay to the next. The worker is able to tell just about what he can count on, and he is able to plan ahead. If he wants to buy a house and pay for it in a series of payments, he can do so without the fear of the nearly complete absorption of a slim pay by the month's instalment.

The skilled worker, especially, appreciates the benefits of this steady wage. As an individual, when there is plenty of ordinary work, he is able to make large earnings. When a particularly hard job comes through, however, or when a new job must be developed on day work, because he is skilled, he usually is called upon. Such a condition cannot exist under the group system. The hard jobs and the easy jobs are pooled together, and the same bonus is earned by all. The better man with the higher rate gets the higher earnings regardless of whether or not he did all the mean and day-work jobs of the group.

Assured a Steady Flow of Work.—Most good workers like to work steadily all day long without undue delays. When jobs are given out to individuals by the foreman, the worker often runs out of work because the foreman, either through carelessness or in the rush of his work, has neglected to plan ahead. The worker must hunt up the foreman before he can go ahead. Often the foreman is busy or is off in another part of the shop, and the man must stand around in idleness for some little time. Obviously the worker does not wish to do this when he is paid for what he produces.

Under the group system, this does not occur, for the group leader whose own earnings are tied up with those of the group is very careful to see that each man is working to the best advantage and that he has plenty of work ahead of him.

Man Gets Work for Which He Is Best Fitted.—Everyone likes to do that which he can do well. When a man is working in a group, he is assured of getting the jobs he can do best, for his efficiency affects the group's efficiency. The group leader plans this very carefully, and since he is close to both the man and the work, he is able to give out jobs to the best advantage.

System of Promotion Is Provided.—An ambitious man, working on the floor of a shop often feels that he is a mere link in the chain of production and that any particular merit which he may have will not be recognized. Too often this is true where there is no organized plan for finding and promoting men.

In a group, the man realizes that one of his fellow workers has been recognized and made group leader. This shows him that the management is interested in men as individuals. He also knows, whether he expresses it in so many words or not, that no man can remain stationary but must either progress or go back. Thus the present group leader will either be promoted to a position of greater responsibility, be demoted, or be separated from the job from some outside cause. There will be an opening, an opportunity for a step ahead, and the man, being ambitious, will have previously demonstrated his ability. If he gets the job, he is satisfied that he has a chance to better himself and will try all the harder to fit himself for further advancement. If he does not get it, he will probably be able to find out why not, and if for any reason other than sheer incapability, he will be ready to work all the harder so that when the chance comes he will not be found wanting.

Working Environment Made More Pleasant.—Many times a man dreads going to his work each day simply because he is working in an unfriendly environment. Friendliness may be decidedly lacking where each man is striving individually to produce all that he can. If the man is weak physically, he may be imposed on and bullied by his fellow workers. They may grab all the best jobs, crowd him out at the tool-room window, and generally make things very unpleasant.

All this is changed under the group system. A group, as soon as it is organized, becomes in a manner a team. Each member realizes that he must cooperate with every other member if he is to benefit to the fullest extent. As the group becomes older, this perfunctory cooperation ripens into a real group spirit. Each member has a friendly feeling towards the others,

which is often carried outside the working hours. Instead of the bitter competition that existed between the individual workers, there is only a spirit of friendly rivalry to see who can produce the most and the best work. Each is ready to commend a good effort on the part of a fellow worker and is in turn made glad when he receives commendation. Such an atmosphere cannot help but make working hours more pleasant.

DISADVANTAGES OF THE GROUP SYSTEM

Against all of these advantages, there are some disadvantages in the group system, and these also must be thoroughly discussed and clearly understood before one can intelligently pass on the merits or demerits of the group system.

Hard to Care for Incomplete Jobs.—It is harder to handle jobs which are not completed at the close of a pay period. Ordinarily, the group should so plan its work that there are no incompleted jobs upon which some work has been done at the end of the pay. Since the group is paid on the basis of shipments of finished work, they do not get paid for work which has been done on only partially finished jobs. Such jobs will be finished up during the next pay period, and the group will receive pay for the whole job at the end of that pay period. Thus incompleted jobs have the effect of making the bonus slightly lower for one pay than is actually made and slightly higher for the next pay. The average of the two pays is the same as if all jobs had been completed at the end of each pay. The percentage of incompleted jobs is generally small, so that this disadvantage is slight.

No Check on Allowances on Individual Jobs.—Under the individual system, it is comparatively easy to get a check on any allowance—time or money—on any particular job. If there has been no "time juggling," both the number of hours worked and the number of hours or cents made will be shown on the time slip for the job.

Under the group system, there is no way of checking an individual job other than timing the worker while he is doing it. It is not often necessary, however, to check allowances, and if it is really necessary, the watch will give a much closer check than the time slip.

No Check on Individual Efficiency.—It is not difficult to check the efficiency of one worker working on an individual basis. His earned bonuses will be an exact index of his working

efficiency. When the same man is working in a group, his individual output is absorbed in the output of the group and is lost sight of. The only check which may be had is that obtained by observation and the opinion of others.

Sometimes Hard to Find Right Man for Group Leader.—It is not always possible, when organizing a new group, to find just exactly the type of man that makes a good group leader. This, while not a disadvantage of the group system itself, is a difficulty sometimes encountered. It is generally possible to find someone who is capable of handling the group at least temporarily, and a little careful search will generally bring to light a man who has the desired capabilities. Indeed, it often proves that the man who was thought to be unsatisfactory and who was given the job only temporarily turns out to be a satisfactory group leader. The chance which he has to show what he can do often spurs him to efforts of which he was not thought capable. This performance, coupled with a change of attitude which greater responsibilities often produce, makes a first-class group leader of one who was thought to be but a follower.

Smothers Initiative and Self-reliance.—It may be said that working in a group tends to smother the initiative of the individual. It may smother the initiative of those who never had much to start with and such initiative as would be shown only under the most favorable circumstances. On the other hand, it has been shown how the individual feels that he is less unnoticed when working in a group and that he has a chance to advance to the position of group leader. Surely such a feeling would enhance rather than smother initiative.

Exceptional Ability Is Penalized.—It may also be stated that the exceptional ability of the highly skilled worker is penalized when he must work in a group, and that he is working hard and producing a lot for the other less skilled men. This would be true if the rates of all the men in the group were the same regardless of ability. Such is not the case, however, and it has already been shown how highly skilled workers are rewarded for their exceptional ability by receiving more in proportion of the group earnings than the less skilled man.

Class of Work Where Group System is Applicable.—There has been much discussion as to the feasibility of applying the group system to different kinds of work. In the opinion of some, the group system is limited to assembly work of a standard nature

where a constant sequence of operation is followed. This, however, is erroneous. The group system, of course, will work better on some lines of work than others, but this is also true of the individual system.

The kind of work that is best fitted for the group system is the making of some standard part or apparatus upon which a definite number of operations are always performed in the same sequence. This condition permits an exceptionally efficient layout, for the work may be divided so that each operator performs one elemental operation. Since the operator does only a small part of the job, he becomes highly specialized and proportionally more efficient, making it possible for him to produce more with less fatigue. Although it is recognized that the group system is best adapted to assembly work on standard apparatus, the advantages are by no means confined to this kind of work.

It can be truthfully said that the group system can be applied to any work where it is practical to use an incentive system, with such exceptions as very large machine tools and work where only one operator is required to turn out the total desired output. In fact, the group system makes it possible to establish incentive systems which will not be feasible under the individual system on such labor as storeroom crews, material-handling crews, furnace crews in foundries, and the like.

The group system has been used to advantage on a number of the same kind of machine tools doing work of a varied and miscellaneous nature and has brought about an equality on this kind of work which would be almost impossible under the individual system. It can be successfully applied to a number of milling machines, lathes, boring mills, planers, drill presses, grinders, or any other kind of machine.

It is often the case that, because of expansion, new machines are added to the plant equipment. These machines, because of improved design and sturdier construction, are able to operate at higher feeds and speeds than the old machines. Where the plant is doing a large amount of miscellaneous work, it is hard, if not impossible, to control the flow of work to each individual machine. Even if it were possible to control the flow of work, it would not always be possible to do a given job on the same machine every time it came through, for that particular machine might be scheduled with work for some time to come. The control of such a condition requires a great deal of supervision, and it is

often necessary to call the time-study department in on the same job several times. If these machines are placed in a group, it is possible to determine the proportion of work which may be done by each machine, and a weighted average of feeds and speeds can be worked out. As a result, although the new machines will be able to do considerably better than the established time, the older machines may not quite meet the time. As a group, the machines will be able to better the established time, and hence the operators will be able to earn a bonus if they work to good advantage.

It must be remembered that, as has been previously said, it would not be advantageous to group a number of very large machines where the number of jobs handled are few and the time allowed for one piece is large.

Some examples of work where the group system has been successfully and advantageously applied are foundry molding (bench, machine, and floor), core making, foundry furnace work, casting cleaning, assembly and fitting work (standard and miscellaneous), coil winding, painting, switchboard wiring, storeroom work, laboring-crew work, material handling, packing and crating, loading cars for shipment, machine-group work, storeroom and maintenance work.

Size of the Group.—The success of a group is by no means independent of its size. In general, it is true that the smaller the group, the better is the fellowship and cooperation between the members of the group, but this may be carried too far. Experience has shown that when the work is not scattered over a large area, groups composed of as many as 15 members work very smoothly and efficiently. Thus it may be said that as a general rule the size of the group should not exceed 15 men, but varying conditions will provide many exceptions.

On an assembly which is divided into 20 separate operations, each of which requires different tools, equipment, and materials and each of which is dependent on one or more preceding operations, the group should consist of 20 men. In this case, it would not be wise to decide that 20 operators are too many and that the group ought to be split up into two groups. If this were done and each group did half the work on the assembly, it is quite probable that the group doing the first half of the work would not give the other group proper consideration. The first group might purposely forget that by doing their part of the

work correctly, they could make it easier for the second group to do their share of the work. Rather they would be likely to slight their work as much as possible, knowing that the second group must do what they have left undone in order to complete the assembly. If two separate groups were formed where, by each man doing two operations, each group performs the completed assembly, there would be a duplication of tools and equipment, and it is quite likely that an unfriendly rivalry would exist between the two groups, each wishing to get the better tools and material. In this case, it is obviously best to include all the operators in one group, and on work of this kind, a group of this size or even larger will not prove unwieldy.

In the cleaning department of a large brass foundry, a group of 35 men was organized and has been operating successfully for 3 years. It was not practicable to try to divide the work up into separate divisions. Cooperation was needed between all the men so that help would readily be given in handling the heavier work. The group members automatically see that each man works steadily, and since the work is comparatively simple, the need for instruction and close supervision of new men is not great.

In a machining department, a group of 25 milling machines was formed, 15 horizontal and 10 vertical. All the horizontal machines were located together physically, and all the vertical machines were similarly grouped, but the two groups of machines were separated by some drill presses. The men on the horizontal millers could not see the men on the vertical machines and *vice versa.* The group leader had a hard time keeping in touch with all of his men. The number of jobs handled each day was large, and the group leader was able only with the greatest difficulty to keep each man at work and give necessary help and instruction. The group efficiency hovered around 105 per cent pay after pay, although apparently it should have been at least 130 per cent. After a thorough investigation of conditions, it was decided that the group was too large and too widely scattered. Accordingly the horizontal machines were formed into one group and the vertical machines into another. The next pay each group made about 120 per cent and have since gradually worked up to 130 per cent, sometimes even going as high as 135 per cent.

The minimum size of a group is, of course, two, and in some cases, it is desirable to form a group of this size. Where only two

men are needed to do a particular class of work, and where by working together they can work more efficiently than by working alone, the formation of a group is advisable.

Organizing the Group.—The initial recommendation for the organization of a group may come from one of several sources. The suggestion may come from the foreman, general foreman, superintendent, or the time-study man, or it may originate with the men themselves. As a rule, such recommendations are made by the time-study department as part of their regular line of work. The recommendation is usually made because it is felt that some of the advantages previously discussed will be realized. When the advisability of forming a group has been recognized by all concerned, the next step is to do the actual organizing.

The first and probably the hardest task in organizing is the selection of a suitable man for group leader. This is done by the superintendent, foreman, and the head of the time-study department. It is sometimes necessary to go outside the department to find a man who has the necessary qualifications for group leader. If there is no man suitable among the operators who will compose the group, men doing similar work in other departments must be considered. If it is at all possible, the group leader should be chosen from the men in the group. Not only is he sure to be more familiar with the details of the work, but also the psychological effect on the other men is better. If they see one of their fellow workers promoted, they will feel that they too will be considered when any change is made.

The desirable qualifications for a group leader are many, and it is probably impossible to find one man in whom they are all combined. First, the group leader should be reasonably familiar with the work the group is to do. He should be something of an instructor, for he trains all new men coming into the group. He also should be able to give help and information to the older men on any difficulty that may occur. The group leader supervises the group and is held accountable for the conduct of all of the members. He should be able to recognize what each individual is best fitted for and place him accordingly. He should be able to interpret drawings and manufacturing information correctly. It is desirable that he have planning ability, for he orders all supplies and tools and assigns all jobs to each individual in the group. He must keep work ahead of each

man and be certain that it is such work as the man can do. The ability to write legibly and to do simple arithmetic is also important, for the group leader turns in all time and shipping reports for the group and generally, if at all interested in his work, keeps a record of group earnings as a check against possible mistakes in the payroll division. The group leader should have a sense of responsibility, for he is held responsible both by the company and the members of the group for the quality and quantity of the output produced. Last, and perhaps most important, he should be a leader of men, one who can inspire confidence and gain cooperation. He should have a good understanding of human nature so that he may know what to expect from his men. He should never take advantage of his position as group leader but should devote all time not otherwise occupied to actual production.

After the group leader has been selected, the next step, that of picking the members of the group, is comparatively easy. It is decided, usually by the time-study department, what operations are to be done by the group. Those operators who have previously been doing this work are those who in the future will compose the group.

The last step, that of completing the paper work attendant to and securing the approvals necessary for the formation of the group, varies somewhat with different company organizations. For the sake of clearness, it will be best to take one definite example of organization procedure and follow that through. The procedure followed by the Westinghouse Electric and Manufacturing Company has been chosen for that purpose. An incentive system known as "standard time" is used. Standard-time values are set on all jobs when such values may be intelligently determined. Each operator has two rates: a day-work rate at which he is paid for day work or work where he fails to meet the allowed-time value, and a higher standard-time rate at which he is paid if he meets or betters the established value.

After the details of the formation of a group have been worked out, a formal recommendation for the organization of the group is made to the group committee on the form shown in Fig. 61. Copies of the recommendation are sent to the superintendent of the time-study department, the rate and occupation committee, and the works accountant. The form on which the recommenda-

Form 11871
W. E. & M. Co.
Works Dept.

Date 5/1/25

GROUP COMMITTEE—

We recommend the { organization / [redacted] } of { [redacted] / Std. Time / .... } Group in Sec. F-12

This group will perform such work as:

Assemble Shunts, magnets, relays and details.

Personnel, details of rates, etc., are as follows:

Section F-12
Group #1
Title Shunts, magnets, relays, & details.

Check No.	Name	D. W. (S. T.) [redacted] Rate	Occupation	Job No.	No. Class	Max. Key Sheet D. W. (S. T.) [redacted] Rate
134	Fred Henderson(Gr.Ld.)	.66	Fitter	4	B-1	.66
183	Alfred G. Cline	.57	"	5	C-1	.57
86	George Baldi	.51	"	5	C-1	.57
1	Katherine Faulkner	.32	"	3W	EW-1	.33
3	Cecelia Furbish	.27	"	3W	EW-1	.33
5	Helen Daugherty	.31	"	3W	EW-1	.33
15	Bertha Rose	.35	"	3W	EW-1	.33
32	Rachel Schulte	.35	"	3W	EW-1	.33
39	Katherine Hipnarowski	.35	"	3W	EW-1	.33
46	Jennie Johnson	.35	"	3W	EW-1	.33
47	Minnie Ullum	.35	"	3W	EW-1	.33
		4.39				4.44

Supervision Rate........

Signed:
General Foreman J. K. Walt
Dept. Accountant Ed. Fitts
Foreman Rate Setter R. Clawson
Superintendent T. T. Kent

The total of the individual
Day Work (Std. Time)
[redacted] Rates of this Group
shall not exceed $4.44 per Hr.

Approved:
Rate & Occupation Committee Wm Smith
Works Accountant L. R. Schneider
Rate Department C. A. Wood

(This form must be type-written)

FIG. 61.—Group organization sheet.

tion is made shows the section in which the work will be done, the number by which the group will be identified, and the title which indicates the kind of work the group will do, together with all necessary information about the members of the group such as name, check number, occupation, job number, the job class, day-work rate, and the maximum rate allowed for that class of work. The total day-work rates should not exceed the total of the maximum allowed rates.

If the group is approved, the recommendation is signed by the chairman of the rate and occupation committee, the works accountant, and the superintendent of the time-study department. One copy of the recommendation is kept on file in the office of the superintendent of the time-study department, one copy is returned to the departmental time-study foreman, and one copy is sent to the departmental accountant.

After approval has been given for the organization of the group, new rate cards are made out for each individual in the group, showing him to be a member of the group and giving his occupation, job number, class, and fixed rate. These cards are approved by the foreman, general foreman, superintendent, time-study foreman, and rate and occupation committee. These cards, regularly approved, will identify each operator as a member of the group. The group is now organized and officially recognized, and time values for the work to be done in the group are marked accordingly.

Reporting Completed Work and Time.—The form shown in Fig. 60 is the group time slip and is made out by the group leader as shown. The check numbers and names of all members who worked during the current pay period are recorded, and opposite the date, the number of hours each worked in the group. This time slip is turned over to the timekeeper at the end of each pay period. The payroll clerk uses this record of the group time in distributing the time allowed for the work done in the group.

As work is completed and shipped by the group, the group leader makes out what amounts to a shipping report. This he does as shown in Fig. 62 if the job is a standard-time job. These slips are turned in to the time clerk who posts the number of pieces completed against the number required, and checks the time allowed for the operation. The slips are then turned over to the payroll clerk who multiplies on each slip the number of pieces completed by the time allowed for each piece and extends

the total allowed time in the space provided. At the end of the pay period, all of the time slips are collected and a grand total of all of the total allowed times is computed. This grand total is known as the total allowed time for shipments made by the group, and it is distributed among the group, a certain amount for each hour worked in the group.

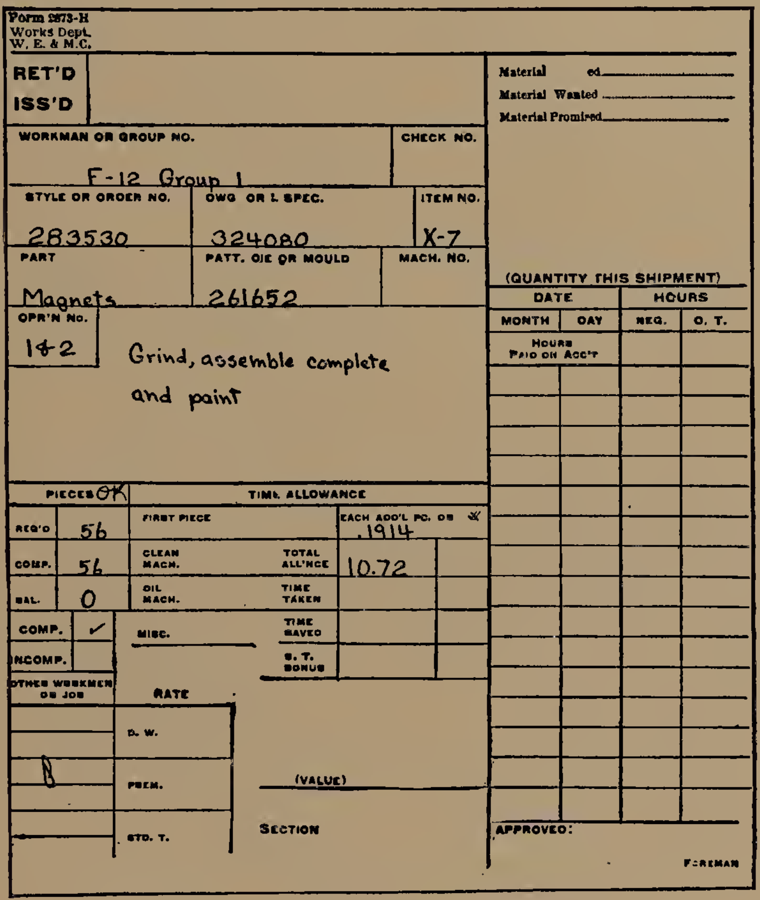


FIG. 62.—Report of a completed standard time job.

All of the work done by the group may not have a time allowance. On such work as repair, experimental, development special, and the like, it is difficult intelligently to establish correct and consistent time allowances, and these jobs are usually done as day work. The group is paid for the time actually taken at the fixed day-work rate. The time-study man and the foreman decide whether or not a job is to be done as day work. If it is, the time taken is approved by them as shown in Fig. 63 before being accepted by the time department. Day-work hours in

the group are distributed among the members of the group in the same manner as standard-time hours.

Distribution of Group Earnings.—The group distribution sheet is shown in Fig. 64. On this sheet is figured the proportion in which group earnings are to be distributed among the members of the group. Figure 64 shows a complete example of distribu-

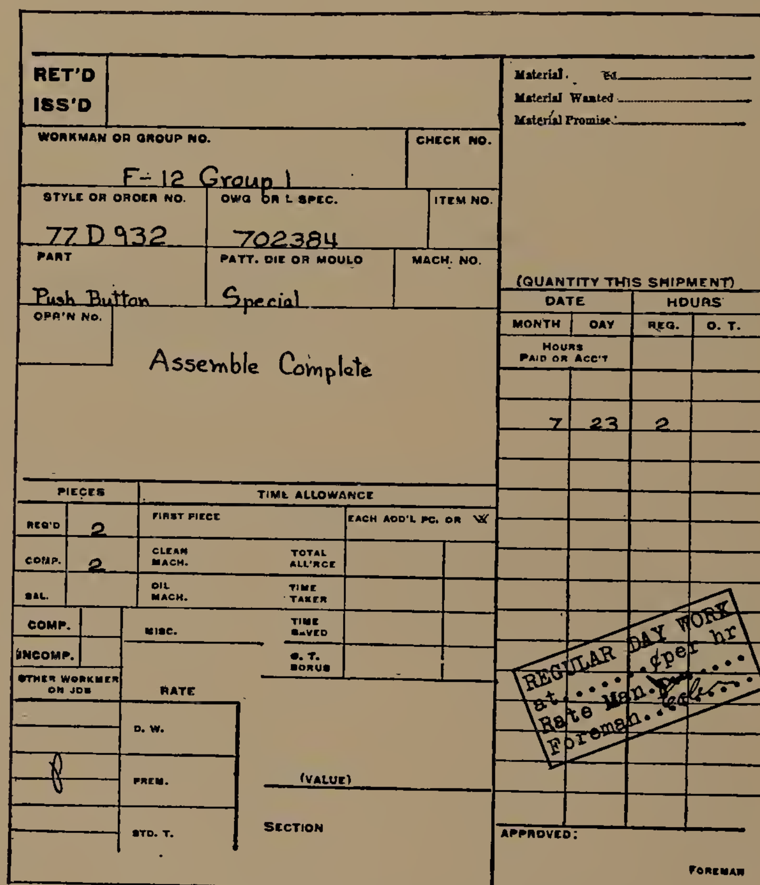

RET'D
ISS'D
Material ... Ed.
Material Wanted
Material Promised
WORKMAN OR GROUP NO. F-12 Group 1
CHECK NO.
STYLE OR ORDER NO. 77 D 932
DWG OR L SPEC. 702384
ITEM NO.
PART Push Button
PATT. DIE OR MOULD Special
MACH. NO.
(QUANTITY THIS SHIPMENT)
OPR'N NO.
Assemble Complete
DATE: MONTH 7, DAY 23
HOURS: REG. 2, O. T.
HOURS PAID OR ACC'T
PIECES: REQ'D 2, COMP. 2, BAL.
TIME ALLOWANCE: FIRST PIECE; EACH ADD'L PC. OR %
CLEAN MACH.; TOTAL ALL'RCE
OIL MACH.; TIME TAKEN
MISC.; TIME SAVED
COMP.; INCOMP.
O. T. BONUS
OTHER WORKMEN ON JOB 8
RATE: D. W.; PREM.; STD. T.
(VALUE)
SECTION
REGULAR DAY WORK at ... ¢ per hr Rate Man ... Foreman ...
APPROVED:
FOREMAN

Fig. 63.—Report of a completed day work job.

tion among the operators who worked during the pay, as shown on the time slip in Fig. 60. The number of hours done on the day-work basis are totaled, and this amount, 30 hours, is noted in the space provided under Summary of Details marked Hours Worked Day Work. The total number of hours worked in the group, 1139.25, as taken from the group time report and checked against the attendance records, is placed under the heading Total Hours in the Group. This amount divided into the hours worked day work gives the percentage of time worked day work and is

recorded as shown. The total allowed standard-time hours for shipments, or 1481.04, is recorded under Standard-time Hours

GROUP EARNINGS—STANDARD TIME SYSTEM

Group Title Shunts, Mgts., Relays & Details.

Group No. 1 Sect. F-12 Pay Ending 7-31-25

SUMMARY OF DETAILS

Hours Worked "Day Work" - - - - - ✠	30.00	(%)
Total Hours in Group - - - - -	1139.25	2.633
Standard Time Hours for Shipments Made - - ✚	1481.04	(%)
Hours worked "Standard Time" - - - ★	1109.25	133.52

DETAILS OF DISTRIBUTION

A	B		C		D		E		F		G		H	I	J		K		L		M	
CHECK No.	CHECK BOARD HOURS		HOURS OUTSIDE GROUP		HOURS IN GROUP: TOTAL		HOURS IN GROUP: % 2.633 DAY WORK		HOURS IN GROUP: STANDARD TIME		% 133.52 "HOURS TO BE PAID FOR" AT STANDARD TIME RATE		RATE: DAY WORK	RATE: STD. TIME	INDIVIDUAL EARNINGS: FOR "DAY WORK" IN GROUP		INDIVIDUAL EARNINGS: FOR "STANDARD TIME" IN GROUP		INDIVIDUAL EARNINGS: FOR "WORK DONE OUTSIDE GROUP"		INDIVIDUAL EARNINGS: TOTAL	
1	96		2	2	93	2	2	46	91	04	121	55	.32	.35		79	42	54		80	44	15
3	113	2	3		110	2	2	91	107	59	143	65	.27	.30		79	43	10		81	44	70
5	109		3		106		2	79	103	21	137	80	.31	.34		86	46	85		93	48	65
15	104	3	2	3	102		2	68	99	32	132	61	.35	.39		94	51	72		96	53	60
32	113	2	3		110	2	2	91	107	59	143	65	.35	.39	1	02	56	02	1	05	58	10
39	113	2	3		110	2	2	91	107	59	143	65	.35	.39	1	02	56	02	1	05	58	10
46	104	2	2	3	101	3	2	68	99	07	132	27	.35	.39		94	51	59	Late .09	96	53	40
47	113	2	3		110	2	2	91	107	59	143	65	.35	.39	1	02	56	02	1	05	58	10
134	113	2			113	2	2	99	110	51	147	55	.66	.73	1	97	107	71			109	70
183	96				96		2	53	93	47	124	80	.57	.63	1	44	78	62			80	05
86	113	2	29		84	2	2	23	82	27	109	86	.51	.57	1	14	62	62	14	79	78	55
TOTAL					1139	1	30		1109	1	1481	04										

Amounts marked ✠ Must Balance. ✠ ★ ✚

Amounts marked ✚ Must Balance.

Amounts marked ★ Must Balance.

Column "Earnings for Work Done Outside Group" Includes O. T. Bonus, Supervision, Inst Period, Etc.

Earnings for "Day Work" in Group / Hours worked "Day Work" = Average earned rate per "DW" hour

Earnings for "Standard Time" in Group / Standard Time hours for shipments made = Average earned rate per "S.T." hour

Include O. T. Bonus, Supervision and Instruction Period Before Dividing.

Average Earned Rate	
Per "DW" hour	Per "S.T." hour

Fig. 64.—Group earnings sheet showing details of distribution.

for Shipments Made. The number of Hours Worked Standard time is equal to the Total Hours in the Group less the Hours

Worked Day Work, or 1139.25 – 30.00 equals 1109.25. Then 1481.04 divided by 1109.25 multiplied by 100 will give 133.52, the standard-time efficiency of the group. The day-work percentage gives the proportion of the hours that each operator worked in the group for which he is to be paid at his day-work rate. The standard-time percentage multiplied by the hours worked standard time will give the number of hours each operator is to be paid for at his standard-time rate.

Under the heading Details of Distribution the actual earnings of each group member are computed. The columns under this heading in Fig. 64 have been lettered to facilitate reference. In column *A* is placed the operator's check number. No names are given, as it is desired to keep the form as compact as possible. Column *B* shows the checkboard hours or the number of working hours each operator was present at the plant. Column *C*—hours outside group—shows the number of hours the operator worked outside the group. This may be either standard time or day-work hours. The difference between columns *B* and *C* gives the total number of hours worked in the group. This is recorded in column *D*. In column *E* is placed the product of column *D* and the day-work percentage. This distributes the day work done by the group among the members in proportion to the number of hours each worked in the group. The sum of the day-work hours recorded in column *E* must equal the total Hours Worked Day Work as shown under Summary of Details.

The number of hours worked standard time is found by subtracting column *E* from column *D* and is noted in column *F*. The hours worked standard time multiplied by the standard-time efficiency gives the number of hours to be paid for at the standard-time rate. In order to check the accuracy of all computations, the sum of the hours recorded in columns *E* and *F* must balance with the totals shown in the lower half of the Summary of Details as indicated by the guiding markers.

In columns *H* and *I* are recorded the two rates of each operator, the fixed day-work rate and the higher standard-time rate. The amount to be paid for day work in the group is recorded in column *J* and is found by multiplying column *E* by column *H*. Similarly, column *C* multiplied by column *I* gives the standard-time earnings shown in column *K*. The amount earned for work done outside the group is computed elsewhere, and only the total is recorded on the distribution sheet under column *L*. The

sum of columns J, K, L, shown in column M, is the total amount in dollars and cents earned by each operator in the group for the pay period.

Overtime in the Group.—If any member of the group works overtime on group work, all that he produces is credited to the group, and the number of hours actually worked is charged against it. The operator who works overtime is given, in addition to his share of the regular group earnings, one-half of his fixed day-work rate multiplied by the number of hours worked overtime. This is the equivalent of the "time and a half" paid individual workers for all overtime work.

The New Employee.—It is very important to handle the new man in a group in such a way that his presence does not affect the group efficiency. It is also very important that each man in the group understands how the new man is taken care of, or else the older men will feel that they are working for the new man while he is learning.

The new man should be allowed to work day work the first two or three days after he joins a group. None of his time will be charged against the group, but they will receive the benefit of all of his work. During the first day or so, the new man will have to ask many questions, receive many instructions, and in general get acclimated to his new surroundings. During this period he will produce just about enough to compensate for the time lost by members of the group in helping him along.

The time-study man and the foreman should keep watch of the new man and should estimate his efficiency periodically, the length of the periods depending upon the speed with which the job can be learned. After the first two days at day work, observation will show that the man is about say 25 per cent efficient. Then all of the man's output will be credited to the group and 20 per cent of his time will be charged against the group. This will mean that the man is contributing to the group earnings in about the same proportion as the other members of the group. The remaining 80 per cent of the man's time is paid for at day work, charged off in the overhead in the learner's account.

As the man becomes more efficient and produces more, the percentage of his time which is charged against the group is increased, always keeping this percentage slightly below the estimated actual efficiency of the man. His estimated efficiency should be about as much higher than the time charged to the

group as the average bonus earned by the group. In this way, the new man can be introduced into the group without affecting the group earnings.

The new man is anxious to increase his efficiency so that he can share full time in the earnings of the group as soon as possible. The group is anxious to have the man learn as quickly as possible so that he will be able to contribute a full day's output for a full day's work. This mutual desire towards the same end will serve to make the learning period of the new man very short. The amount of day work which will be charged to the learner's account will be much less than if the man were learning under an

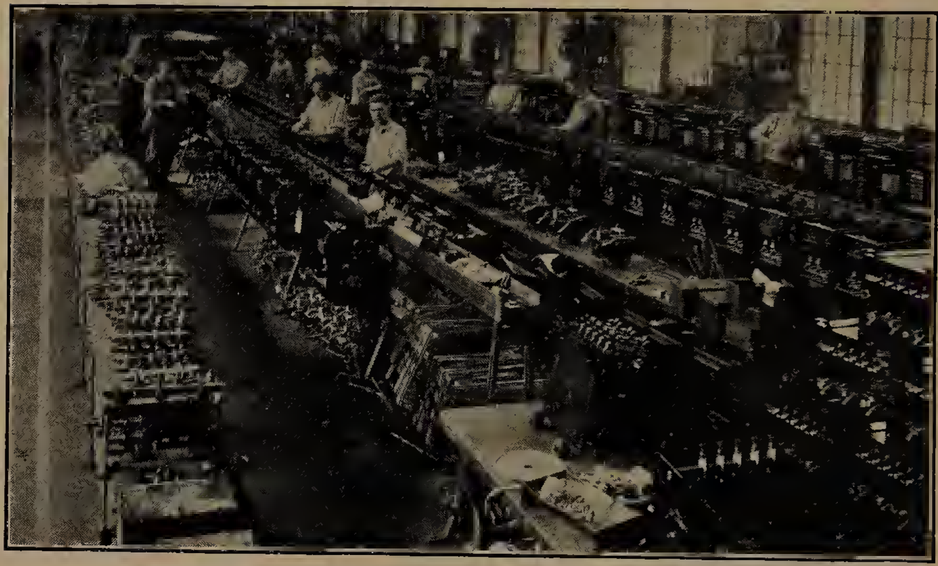


Fig. 65.—Typical group at work assembling auto-starters.

instructor, and the instructor's salary is entirely saved. Thus the group system enables the breaking in or training of new men in the minimum time at a minimum expense with little or no disturbance to the other employees.

Conclusion.—After the group has been organized and has been in operation for a while, little further attention need be given it. A glance at the standard-time efficiency recorded on the group distribution sheet will serve to tell the supervisory force how the group is functioning. If earnings are normal and fluctuate little from pay to pay, no further supervision is necessary. An abnormally low or high efficiency will at once flag the attention of the supervisors, and the conditions which caused this change may be immediately investigated.

New group sheets should be made out periodically in order to assure that the record of group personnel is kept up to date. New sheets should also be made out whenever the rate of any operator is changed. Such a change will affect the average group rate and hence the billing rate used by the cost department for work done by the group.

If there are a number of groups working together in the same department, it is desirable that they work together in harmony, especially where the supply material of one group is the finished product of another. Cooperation will be increased by periodic meetings of all group leaders in the department. This meeting is presided over by the foreman. The group leaders have an opportunity to make criticisms and suggestions in open meeting, and many of their daily problems may be discussed and solved. When the men in each group are working together and when there is a spirit of cooperation among the groups themselves, internal friction has been reduced to a minimum.

CHAPTER XXXVIII

JOB ANALYSIS AND CLASSIFICATION OF WORK

It will be well before closing to say a word about job analysis and classification of work. Because of his constant analytical study of all work in his department, the time-study man will be of great assistance in analyzing all jobs and classifying them properly. He is familiar at the outset with the qualifications necessary to handle any work coming under his jurisdiction, and since he and all other time-study men in the plant are working under standardized methods, the analyses furnished by the time-study department as a whole should be very nearly the same for similar types of work. The value of these standardized analyses in classifying work should be readily apparent.

The heading up of job analysis and classification of work may well be delegated to someone in the time-study department or to someone who has had time-study training. The analytical viewpoint developed by a time-study man will be a great asset in carrying on this most important work.

Job Analysis.—Job analysis is the process by which the data significant to a job are uncovered for arrangement into some compact summary form. It is the method, and not the result, of auditing individual jobs. In plants where no job analysis has been made, it is not uncommon to find two men working on similar jobs receiving widely different rates of pay. When such a condition becomes known to the lower-paid man, it cannot help but cause active dissatisfaction. It is one of the aims of job analysis to uncover such conditions with a view to correcting them.

A concise analysis of a job in the hands of the employment supervisor will enable him to pick a man suited for the work. Without the analysis, the only hiring specifications that the employment supervisor has are those which he notes mentally in his trips about the plant. Such specifications are from their very nature anything but definite and exact. On the other hand, job specifications established after careful analysis furnish

a definite means of placing the right man on the right job and serve, more than anything else, towards eliminating the misfit in industry.

Job analysis also serves to point out unfavorable working conditions and goes hand in hand with the efforts of the time-study man to bring about a pleasant working environment. A calm analytical survey of any job will bring to light poor conditions and accident hazards which may easily escape notice in the hurry of getting out everyday production. Where poor conditions are discovered, they should not merely be noted, but active steps should be taken towards their elimination.

Functions of Job Analysis.—One of the chief functions of job analysis is to determine the standard occupations in the plant. By occupation is meant the general nature of the work to be done. It should be clearly designated by a descriptive name such as "painter," "tinsmith," or "pipe fitter." Names which are in common use in other plants should be chosen in order to enable the employment supervisor easily to determine what line of work a new applicant has been doing.

Each occupation should be subdivided into operations, and the operation should denote the specific process to be performed. Under the occupation of painter might be given such operations as "paint with spray gun," "varnish," and "maintenance work." The operation may be still further subdivided into jobs which give the specific process applied to certain parts in a given department. The operation "paint with spray gun" under the general occupation of "painter" might have listed under it such definite jobs as "paint sheet-iron controller cabinets" or "paint motor brackets and end bells." Thus all jobs in each occupation are clearly analyzed.

Job analysis further leads to the classification of jobs in accordance to their relative value in industry. It makes possible the establishment of definite wage rates in proportion to the value of the work being done, thus bringing about satisfactory methods of compensation. It divorces the consideration of possible earned rates under an incentive system when bargaining with a man for a job.

Standardizing Occupations.—The general occupations which occur in the plant should first be listed and combined under standardized names so that there will be no duplication. A list of the occupations in each department may be obtained through

the combined efforts of the time-study man and the foreman in that department. They will together go over the work of the department and classify it into occupations.

These occupation lists from each department should then be gone over by the man who is heading the work of making the job analysis. He should strive to classify and list under standard names all the occupations set forth thereon. In cases of doubt, he should go back to the department concerned and ascertain just what was meant by a particular occupation name. In this way, he will eventually arrive at a condensed list which will contain every occupation which exists in the plant. In large plants doing a varied line of work, this list may contain all but the most specialized occupations, while in smaller, more standardized plants, the list will be fairly short.

As has been mentioned before, occupation names that are common throughout the district should be used wherever possible as an aid to the employment supervisor. Standard names also should be used so that supervisors and workmen in the various plant departments will have a common understanding of what is meant.

Description of Occupations.—After all occupations have been determined and listed, each should be thoroughly studied and should be described in clear concise terms. These descriptions will aid in clearing up any ambiguity which may be left by a rather general occupation name. These descriptions should be given in a standard manner and may take the following form.

COPPERSMITH

Duties.—Manufacture or repair and coppersmith work of any character and for any purpose.

Qualifications.—Must be experienced in all phases of coppersmith work and able to work to drawings, sketches, or samples and layout, and form from sheet copper such articles as copper kettles, funnels, copper pipes, and pipes and fittings for gas ejector equipment. Must be skilled in bending, shaping, and fitting pipes for high-pressure steam, water, or other purposes. Must also be capable of tipping wooden parts with sheet metal, soldering joints in copper wire, and repairing gas tanks and radiators. Must be thoroughly familiar with cutting patterns from drawings and with the use of proper fluxes in brazing, and must be skilled in the use of brazing furnaces or gasoline blow torches. Must also be familiar with working other metals, such as brass and sheet aluminum. Should have had similar experience in railroad or industrial shop. Sheet-metal worker, tinsmith.

TURRET LATHE

Duties.—Operation of standard types of modern turret lathes on all classes of work.

Qualifications.—Must be able to work to drawings and figure dimensions and be acquainted with proper lathe and cutting speeds for different classes of work and materials. Must understand thoroughly bar and chuck work, forming, and production of varied and intricate pieces. Must be familiar with Warner and Swasey, Jones and Lamson, Pratt and Whitney, and Gisholt type of turret lathes, and be skilled in setting up machine, mounting irregular-shaped pieces, and operations on any type of work. Should understand setting tools and stops. Should be thoroughly experienced in the use of calipers, micrometers, snap, plug, and limit gages and should be able to turn out accurate work. Should have had experience on this class of work in large manufacturing plant, machine-tool factory, or general machine shop. Lathe operator, boring-mill operator, automatic-screw machine operator.

Advantages of Job Analysis.—As a result of job analysis, executives, foremen, and workmen are caused to think seriously and systematically about jobs and the possibilities of better working conditions. When a foreman has analyzed and definitely noted the characteristics of and requirements for a particular job, he no longer fills it blindly but examines intelligently the suitability of the men the employment department sends to him.

A closer relationship is established between the working force and the executives, which lessens the likelihood of disagreement. The workers realize that the management is taking a minute interest in every job, and they do not feel lost or buried from sight. Thus an intelligent attitude on the part of the working force is encouraged.

There is no doubt that the workman is benefited by job analysis. Not only is the man placed on the job for which he is well fitted, but information and suggestions can be given to new employees with a definiteness not hitherto possible. A basis for efficiency ratings is established for the older employees, and increased compensation as they become more valuable on the job is made definite and certain. The foreman knows just what the job is worth and never feels that he has to hold back a raise for fear that he is paying more than the recognized rate for the class of work being done.

A definite line of promotion is established within the department. As each job has been thoroughly analyzed, it is easy to trace just how experience on one job fits one for promotion to a

job requiring superior ability and hence commanding more pay. An intelligent material-handler about machines will learn by observation how to run a simple broaching machine. Experience on running a simple machine tool of this sort will lead him on by successive steps to plain boring-mill work and turret-lathe operation, and eventually he will be able to perform work satisfactorily on an engine lathe. A new source of semiskilled and skilled labor is thus made apparent to the foreman, and he will search his own department carefully before going afield to fill an opening. Jobs are graded with greater ease according to their maximum desirability or according to the amount of skill required. These definite lines of promotion within a department do as much as any one thing towards holding the better and more ambitious men, especially among the lower classes of work.

Demands for better working conditions are definite and are not subject to whim and immature judgment. Job analysis points out possibilities along these lines, and common sense promotes action.

Standard Form of Job Specification.—Practically every plant that has conducted a thorough job analysis has devised its own form for recording job specifications. It is beyond the aims of this chapter to analyze and discuss a number of these forms. Rather it will suffice to give a few of the principal characteristics such a form should possess, with one concrete example.

The job specification card should show in detail the exact nature of the job. Reference to this card should enable anyone familiar with manufacturing practices to visualize the manner of work described thereon. The card should also give a definite list of the characteristics required of the worker on the job. It should list sex, age, experience, strength, height, and other points which are important on that particular job.

All of this information should be listed as concisely as possible. The card shown in Figs. 66 and 67 is designed to give this conciseness and also to enable the noting of the job specifications and requirements with a minimum amount of clerical labor. Only those items which are particularly applicable to the job under consideration are filled in. Initiative is desirable on any job, but where it is not required to a marked degree, the "initiative" square should not be checked. One side of the card gives a description of the job, and the other side lists the necessary attributes of the operator for that job. A generous space is

provided for noting any exceptional features. The items listed on the cards are practically self-explanatory.

One copy of this card should be kept in the employment files, and one copy should be retained by the foreman. When requisi-

JOB SPECIFICATION FOR WORKS EMPLOYES

Occupation........................ No.............. Class.............. Job No..............

Dept..................................... Division.............................. Section..............

THE WORKER:

Age Limits.. Minimum Weight..

☐Man	☐Speak English	☐Strong	☐Accuracy	☐Use Jigs
☐Woman	☐Read English	☐Quick	☐Thorough	☐Gauges
☐Tall	☐Write English	☐Careful	☐Good Memory	☐Templates
☐Medium	☐Common School	☐Patient	☐Read Scale	☐Micrometer
☐Colored	☐	☐Observant	☐Set up Work	☐Prints

Tools Operative Should Own..

Experience (Time) Previous.......................... To Learn.......................... How Taught..........................

Promote From.. To..

Remarks:...

....

....

Westinghouse Electric & Mfg. Co.

Fig. 66.—Front of job specification card.

THE WORK:—

☐Heavy	☐Standing	☐Hot	☐Fumes	☐Day Work
☐Light	☐Sitting	☐Cold	☐Oils	☐Premium
☐Close	☐Stooping	☐Wet	☐Acids	☐Piece Work
☐Rough	☐Reaching	☐Dirty	☐Hard for Hands	☐Standard Time
☐Hand Lift	☐Repetition	☐Dusty	☐Eye Strain	☐Group
☐Crane Lift	☐	☐	☐	

Approximate number engaged in this work: Men.............................. Women..............................

Type of machine tool...

Materials used...

Description of work...

....

....

....

....

....

....

Westinghouse Electric & Mfg. Co.

Fig. 67.—Back of job specification card.

tioning a new worker, it is necessary for the foreman merely to refer to the job identification. Not only does this obviate the constant filling out of cards, but it insures that the job specifications for a particular job will always be the same. If a card were

filled out every time need arose, the specifications furnished the employment department for a particular job would tend to vary with the mood of the foreman and the amount of time at his command. Since the permanent job card is filled out when attention is focused on the task and at a time when it is certain to be carefully examined by those interested, it will contain, as nearly as it is humanly possible to determine, the exact job requirements.

Methods of Analysis.—The man who is conducting the job analysis should get the ideas of anyone who can give him information that is likely to be of practical value. The first step is to send out a questionnaire to each department, asking for a detailed analysis of every job in the department. With this questionnaire should go a list of the standard occupations which have already been established in order to serve as a guide in making the analysis and to minimize the danger of having the same job described in different terms by different men.

The time-study man and the foreman should together fill out this questionnaire. They should set aside a certain period each day and should allow nothing to interfere with its utilization for job analysis until the task is completed. From the work that has already been done on job analysis in various industrial concerns throughout the country, it should be possible to devise in advance a card form suitable to the particular conditions to be analyzed. This card form will be the main part of the questionnaire and need only be accompanied by a complete set of instructions on how to fill it out.

The time-study man and the foreman should first make a list of all the jobs in the department. They may then quickly classify these jobs to the proper occupations, using the standard list for reference. They are then ready to analyze each individual job in detail. They should first make out cards for all jobs that come under a given occupation. Then by comparing these jobs one with another, they will be able easily to ascertain the relative ability required on each. This will be a great aid in enabling the intelligent checking of the items of importance listed on the cards. As has been mentioned before, only the items that cover special or unusual conditions should be filled in.

A review of the cards obtained from a department will tell the job analyst just how thoroughly the analysis has been made. If there is any doubt at all as to the accuracy of the information

submitted, he should himself go into the department and investigate the job first hand. There he may talk with the man actually engaged on the job as well as with the time-study man and the foreman. He may sometimes receive further information by questioning the employment supervisor and the executive at the head of the department. From the detailed information thus obtained and from the broader viewpoint of job analysis in the shop as a whole, he will be able to assure himself as to the completeness of the information secured from the questionnaire, and he can make all necessary corrections or additions.

The drawing up of job specifications should go hand in hand with the making of job analyses. After a job has been analyzed in detail, it should be an easy matter to determine the necessary characteristics of the man who is to fill that job. The time-study man and the foreman will make the initial job specifications, and the job analyst will check them in the manner described above, paying particular attention to the views expressed by the employment supervisor.

Classification of Jobs.—After all jobs have been analyzed, their classification follows almost as a matter of course. The chief benefits derived from the classification of jobs are that uniform pay is given for uniform service and that a logical basis for promotion is furnished. Considering the first point, if all jobs that are placed in a particular class as of the same value to industry, it is reasonable to expect that the remuneration given should be the same within a narrow range. A range should be provided, for it is apparent that the longer a man is on a certain job the more familiar he becomes with it and with shop conditions. It is only fair that he should receive compensation for this increased knowledge, and also as a reward for his stability.

Job classification makes definite the lines of promotion that job analysis suggests. As the man becomes capable of doing a higher class of work, he may be promoted accordingly and receive the accompanying increase in pay.

The basis for classification should be the job itself and not the worker. It should be reasonably easy to determine the value of any job to the industry. A man is valuable to a company in accordance with what he does and not in accordance with what he is capable of doing. Thus the job should be classified and the man paid according to what the job is worth. If production on a high class of work falls off and it is necessary to place some of

the men who have been doing the work on a lower-class job, their rates should be reduced accordingly. Only in very exceptional cases where the reduction of rate would cause the quitting of a man for whom it might take years to train a successor should this rule be overstepped, and then only by order of and after careful consideration by the superintendent.

There are several reasons for some jobs having relatively higher values than others. The length of the period necessary to train a new operator is an important consideration. Some jobs require an unusual amount of manual dexterity which may be gained only by long practice. Such jobs are obviously of more value than jobs which may be learned in a short time. Other work may be handled only by those who are physically very strong, and with these, muscular superiority deserves an additional reward. Knowledge obtained by much experience on a certain kind of work or knowledge of conditions which are peculiar to the job at hand is sometimes a reason for extra remuneration. Executive ability as evidenced by group leaders and gang bosses should be suitably recompensed. Working conditions may be such as to make the job less desirable because it is unusually dirty, hot, cold, dangerous, or unhealthy or because of long working hours or hours at an unusual time, and men working under such conditions are entitled to receive more than those more favorably situated. The cost of the material involved in a particular operation may place a premium on a dependable worker who produces little or no spoiled work. These examples should serve to suggest the factors which must be considered when job classification is undertaken.

Making the Classification.—The classification of the majority of jobs in any plant will be comparatively easy. In practice, it has been found desirable to divide all jobs into five classes as follows:

Class A.—This class covers jobs requiring only those masters of their trade who thoroughly understand their work in a broad way and who are competent to work without immediate supervision; jobs requiring leaders in charge of groups, experimental workers, and those on the highest-grade production or tool work. General knowledge of machine tools, speeds, materials, and so on, judgment, accuracy without the use of jigs, and a high degree of skill and dependability are required. Examples: engine-lathe, planer, and boring-mill operators on very large work where great loss is incurred if mistakes are made; engine-lathe operators

on smaller accurate work not depending on grinding for final finish; tool work such as thread gages; machine-tool repair work; winders on turbo and large generator work, and experimental work.

Class B.—This class may require as good a worker on certain specific operations as does the Class A job, but his experience does not need to cover so broad a field, and he requires some supervision; accurate dependable workers with considerable ability and experience but without the thorough knowledge or experience required of those in Class A; operators on accurate or heavy work which is usually repeated. Accuracy, knowledge of speeds and materials, reading of blueprints, and use of gages are required. Examples: engine-lathe operators where work is not especially accurate but is laborious; work on smaller lathes where there is great responsibility, as on commutators and collectors after they have been assembled on shafts; planer operators on medium-sized repetitive work; vertical-boring-mill operators on large work or on accurate difficult work on smaller mills.

Class C.—This class is intended to cover specialists or machine operators rather than mechanics. It is intended to include workmen who have become proficient on specific operations. Examples: engine-lathe operators on repetition work and roughing shafts; planer operators on rough work such as roughing stock from poles; boring-mill operators on small repetition work.

Class D.—This class includes jobs requiring the type of man who is somewhat above the laboring class and who shows a reasonable degree of intelligence and interest in his work, with a desire to learn. On these jobs, in general, the workman is trained for a Class C job. It also covers jobs so simple and requiring so short a time for training that they are not included in Class C. Examples: employees learning to operate engine lathes, planers, and boring mills; those learning to wind; stockmen; filers; chippers; machine helpers; and punch-press operators.

Class E.—This class covers what are usually called laborers. These are unskilled workmen with practically no previous training; men on work where only a small degree of skill, accuracy, or knowledge is needed. The jobs are rough, and the operations are repeated and extremely simple, requiring a minimum time to learn. Examples: truckers, material handlers, sweepers, machine helpers, janitors, and ashmen.

All job cards should be sorted out into five groups, one for each of the above classes. Some few will probably not fall readily into any one class, and these must be taken under further consideration. Generally, consultation with the foreman involved and a first-hand review of the job itself will result in the fixing of the job class.

Conclusion.—As a result of time study and formula work, incentives will be established throughout the plant which will increase production and which will limit the earnings of workers only to their own capabilities. Daily drudgery will be eliminated to a large extent, and the act of soldiering or putting in time will become largely *passé*. Certain definite standards are established, and the workers will try to meet or better them with a zest which may be likened to that displayed by an athlete in piling up points in competition.

Job analysis and job specification will serve to place men in jobs for which they are well fitted and, hence, on which they will enjoy working. Job classification will do away with inequalities in pay and will provide ready channels for promotion. Although all this work was started with the intention of benefiting the employer, it is questionable if he has received a fraction of what he has given. Certain it is that the man today working in a modern systematized industry is receiving higher wages, working shorter hours under better conditions, and doing less drudgery than ever before, and an attempt to return to conditions in vogue 50 or even 20 years ago would be met by a well-founded and stubborn resistance by employers and employees alike.

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